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Geophysical Survey and Site Sampling Investigation

Western Processing Site
Kent, Washington

Sampling and Test Plan Contracting Group

Volume III

Geophysical Survey Report

June 1987

HDR Infrastructure
A Centerra Company

In Association with
Engineering Enterprises, Inc.
Northern Technical Services, Inc.
Farr, Friedman & Bruya, Inc.

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for

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VOLUME III - GEOPHYSICAL SURVEY REPORT

1.0 FOREWORD

This is Volume III of the five volume final report prepared for the Geophysical Survey and Site Sampling Investigation conducted at the Western Processing site during the Fall of 1986. The purpose of the study was to determine the extent of hazardous chemical contamination and to provide a basis for subsequent remedial cleanup activities. The comprehensive final report consists of the following volumes:

- Volume I : Summary Report
- Volume II : Analytical Data (Books 1 & 2)
- Volume III: Geophysical Survey Report
- Volume IV : Photographic Log
- Volume V : Support Documentation

2.0 DOCUMENT DESCRIPTION

The Geophysical Survey of the Western Processing site was performed by Northern Technical Services (NORTEC) of Redmond, Washington. The purpose of the survey was to determine the location of buried metallic containers, buried utilities, non-containerized waste materials, buried or covered foundations, or other anomalies located in the subsurface. Subsurface anomalies were detected through measuring disturbances in the earth's magnetic field caused by buried metallic objects, changes in the conductivity of the soil, or deflections in ground penetrating radar measurements. Geophysical results were then used to guide the soil sampling program.

The following report was prepared by NORTEC after the completion of the Western Processing study. This report includes a general introductory section, detailed information on the technical approach to the project, the results of the survey, and recommendations for future work.

Job No. 280-004

WESTERN PROCESSING REMEDIAL ACTION SITE FINAL GEOPHYSICAL SURVEY REPORT AREAS I, II, III, V, IX, & X

Prepared for:

HDR INFRASTRUCTURE

Seattle, Washington

April 1987

NORTEC
A DIVISION OF ERT

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1.0 INTRODUCTION

1.1 General

On August 18, 1986 a contract was awarded by the Sampling and Test Plan Contracting GROUP to perform a systematic study of shallow soil contamination at the Western Processing Superfund Site in Kent, Washington. The study was designed to determine the precise nature and extent of hazardous chemical contamination and to provide a basis for certain remedial cleanup activities. In general, the study included: 1) preparation of a detailed study plan which was approved by the GROUP and governmental agencies, 2) the conduct of field investigations, including a geophysical survey, and 3) preparation of a final report describing the investigative procedures and presenting the data developed. This document provides the final results of geophysical survey on the Western Processing Superfund site.

1.2 Background

The Western Processing Superfund Site is located at 7215 S. 196th Street in Kent, Washington. The facility was operated as an industrial waste processing and recycling facility from 1961 to 1983. During its history of operation the facility handled, processed and/or recycled animal byproducts, brewers yeast, and a wide variety of industrial waste products, including solvents, flue dust, battery chips, acids and cyanide solutions.

Review of historical aerial photos and reports prepared by previous investigators suggested that several filled waste water lagoons, reaction ponds, subsurface impoundments, and numerous burial sites of drums and other potentially toxic wastes might exist on site.

The site is officially defined as the Western Processing Property (Figure 1, Areas I and VII) and Off-Property Remedial Action Areas (Figure 1, Areas II-V and VIII-X). The Western Processing Property occupies approximately 12.3 acres. An operations trailer, mobile water treatment plant, several enclosed storage vans, one plastic-lined impoundment, and several areas covered with asphalt paving and concrete slabs are presently located on the property. Mill Creek traverses the northwest corner of the property. The Kent Bicycle Trail occupies a former railroad right-of-way to the east of Area I. A petroleum product pipeline, high-voltage powerlines, and a drainage ditch also parallel the eastern boundary. Further to the east is the active Burlington Northern Railroad line. Area V, which lies adjacent to the west fence, is littered with large vehicles and stacks of heavy construction materials south of Mill Creek.

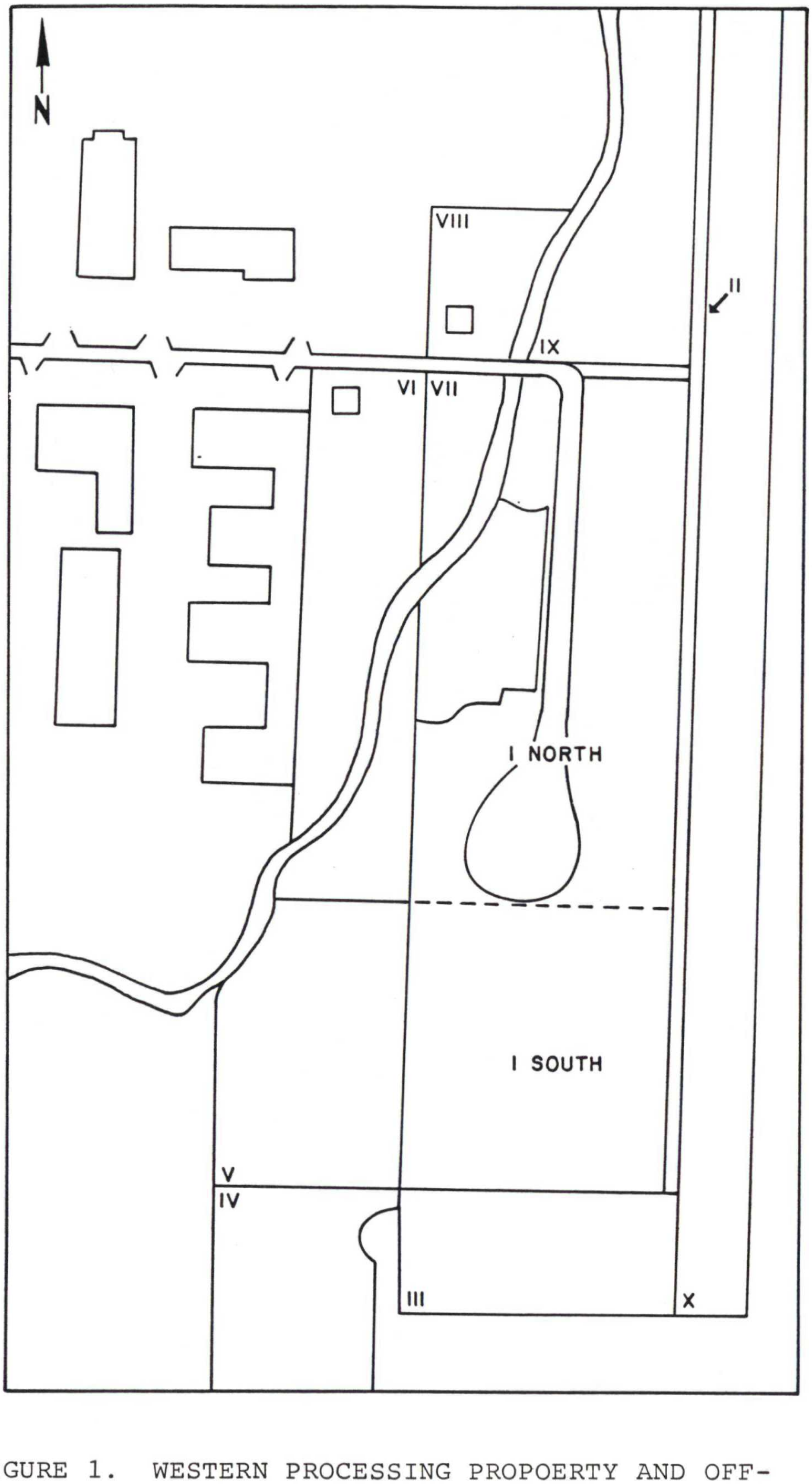

FIGURE 1. WESTERN PROCESSING PROPOERTY AND OFF-SITE REMEDIAL ACTION AREAS.

1.3 Study Objectives

The overall study objectives were to evaluate the precise nature and extent of contaminated materials to be removed from Area I and to assist in determining the extent of certain planned remedial actions in Areas II-V and VII-X. The specific objectives of the geophysical survey were to:

- Locate buried drums, tanks, utilities, and process lines within Area I, and
- Determine the locations of all abandoned or active utilities, process lines, or other pipes leaving Area I and crossing into or ending in Areas II-V and VII-X.

2.0 TECHNICAL APPROACH

2.1 General

The geophysical program performed on the Western Processing site included a total field and gradient magnetic survey, an EM terrain conductivity survey, and a ground penetrating radar (GPR) survey.

In order to facilitate an efficient and timely soil sampling program, Area I was initially divided into two distinct survey segments: a north segment and a south segment. Due to unforseen delays created by a required health and safety upgrade, Area I south was further divided in half in an attempt to keep the soils sampling program on schedule. The preliminary results of these surveys were presented in three reports during November 1986. This report provides the final results of the geophysical investigations in Areas I, II, III, V, IX and X.

2.2 Horizontal Control and the Survey Grid

An initial survey grid based on 75 foot centers was established within the survey area by HDR. Using this grid, NORTEC developed a 10 foot center grid for the geophysical survey with chaining, staking and flagging techniques. All analog and digital geophysical data is annotated with reference to the NORTEC grid. A third grid (Landau grid) was utilized later in the program.

The conversion factors for these control grids are presented below:

NORTEC Grid	HDR Grid	LANDAU Grid
0 N, 0 W	+ 250 N, + 245 W	+ 11.5 N, + 45 W

Within Area I, the geophysical surveys were performed on a north-south oriented grid (Figure 2). EM-31 and magnetometer/gradiometer data were collected on 10 foot centers and

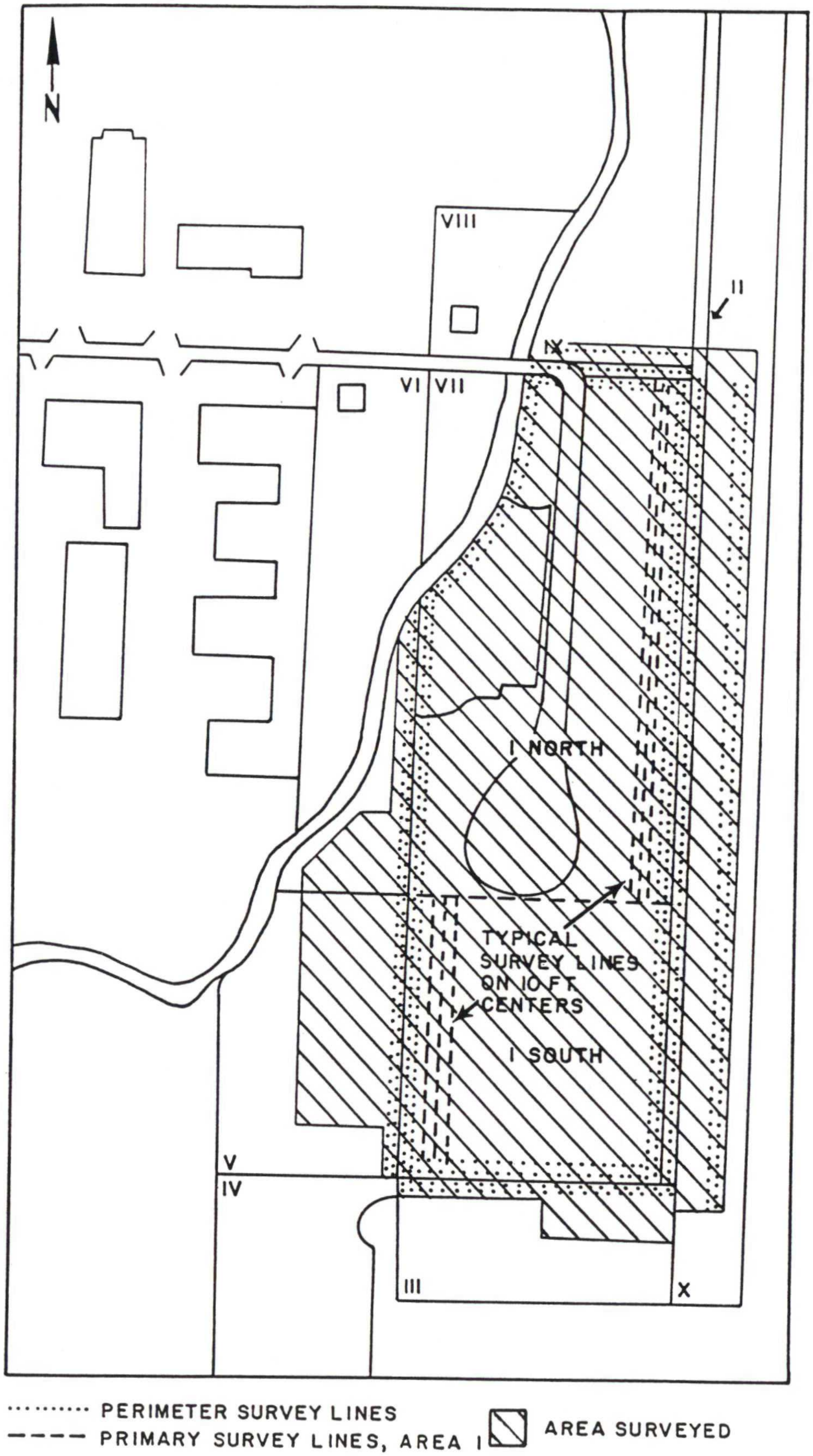

FIGURE 2. GEOPHYSICAL SURVEY AREA.

radar profiles were obtained along parallel tracklines on 20 foot centers. Additional GPR lines were run in other orientations and spacings where required to gather more site specific data.

Two additional GPR survey tracklines were run on ten foot centers inside and outside the perimeter fence in order to locate and map subsurface utility corridors or process waste lines which exited or entered Site I. A single traverse of EM-31 and magnetometer data were collected as a parallel offset to the perimeter fence in Offproperty Remedial Action Areas III and V.

Due to interference from overhead powerlines only radar and EM-31 data were collected in Areas II, IX and X. No geophysical data were collected in Areas IV, VI, VII, and VIII.

2.3 Geophysical Systems

2.3.1 General

The geophysical methods used to accomplish the goals of this study were: a magnetometer survey, including both total field and vertical gradient; a shallow depth electromagnetic (EM) survey; and a ground penetrating radar (GPR) survey. Systems deployed include: an EDA OMNI IV survey magnetometer with internal digital memory and a base station magnetometer; a GEONICS EM-31 with digital recorder; and a GSSI 120 mHz GPR with a digital tape recorder. All geophysical systems were operated in the field according to established Technical Procedures Documents developed specifically for this program (see Appendices A, B & C).

2.3.2 EM-31

The Geonics EM-31 measures the apparent conductivity of the soil to a depth of approximately 20 feet by utilizing the principles of electromagnetic induction. The EM-31 consists of two horizontal coplanar loops, one acting as a transmitter and the other as a receiver, which are separated on a rigid boom by a distance of 3.66 meters. The entire apparatus is carried by one operator at the hip level by means of a shoulder strap. A 9.9 kHz signal in the transmitter coil induces circular eddy current loops in the earth, which in turn produce a secondary magnetic field. The receiver coil intercepts this secondary field, and the EM-31 measures the terrain conductivity by comparing the strength of the secondary field to that of the primary.

The terrain conductivity meter responds to electrical conductivity contrasts in subsurface materials, and it is useful for locating buried pipes and other linear conductors by virtue of their contrasting electrical properties. In addition, the conductivity meter is also very useful for mapping variations in the conductivity of the soil itself. Since soil conductivity is primarily a function of the conductivity of the soil pore water, an added benefit of a terrain conductivity survey on a hazardous waste site is that groundwater pollution plumes can often be effectively delineated.

Daily calibration of the EM-31 was conducted at a central base station according the the QA/QC procedures outlined in Appendix B. The terrain conductivity data were recorded in the field using an OMNIDATA digital POLYCORDER. In addition to providing an efficient RS-232C computer data interface, this recording technique permitted the acquisition of two distinct channels of information from the EM-31, the quadrature phase channel and the inphase channel. The quadrature phase channel yields the apparent conductivity of the soil in units of millimhos per meter, while the inphase channel provides a measure of the terrain magnetic susceptibility, given in parts per thousand (PPT) of the primary field. Experiments by Geonics, the manufacturer of the EM-31, indicate that the inphase channel is about twice as sensitive to the presence of buried metallic objects as the quadrature phase. Thus, the inphase channel of the EM-31 constitutes a very effective metal detector.

The quadrature phase data output is internally calibrated to read directly in units of terrain (apparent) conductivity. Thus plots of the quadrature phase data are quantitatively interpretable in terms of soil conductivity. The inphase data output, however, is given in parts per thousand of the primary field. Plots of these data are not interpretable in terms of soil characteristics, but rather are analyzed to search for disturbance "targets" indicating buried metallic objects. Generally, a strongly negative inphase value (-10 PPT) is thought to be suggestive of the presence of metal.

2.3.3 Magnetometer/Gradiometer

The EDA OMNI IV Total Field Magnetometer with Gradiometer was used in the search for buried metallic objects. This instrument can measure the disturbance in the earth's total field created by iron and steel (ferromagnetic) objects. The magnetometer is particularly effective in this search mode since the high permanent magnetization present in iron pipes and stacks of drums leads to large local disturbances in the earth's magnetic field.

In addition to measuring variations in the earth's total field strength, the EDA OMNI IV magnetic gradiometer has the added capability of performing a simultaneous measurement of the vertical gradient of the earth's total magnetic field. This has been found to be a very effective technique for search applications, in that vertical gradient data tends to have greater lateral resolution than total field data. Thus, multiple buried objects which appear as a single composite total field anomaly can often be individually identified on vertical gradient profiles or maps. This greater spatial resolution is very important on hazardous waste sites in that it can help to reduce the area of search at individual anomalies.

Both total field and gradient data are recorded by an internal microprocessor on the OMNI IV magnetometer, which provides for very efficient post-field data processing via an RS-232C computer data interface. A companion EDA magnetometer was established as a base station magnetometer central to the site, according to the QA/QC procedures described in Appendix C. The EDA internal software enabled automatic diurnal drift correction of the total field data when the two instruments were linked together during the RS-232 data transfer to the computer. The vertical gradient data, on the other hand, do not require a diurnal drift correction, since the gradient measurement is made simultaneously in the OMNI IV gradiometer by two sensors separated by 0.5 meters.

2.3.4 Ground Penetrating Radar

The ground penetrating radar system was utilized in conjunction with the magnetometer and EM-31 systems to characterize shallow subsurface anomalies. The radar system was used to refine and extend the data from the other systems and to locate and track buried utilities.

The ground penetrating radar system consists of an antenna which is towed along the ground; processing and display equipment contained in a small cart or truck; and an electrical/mechanical umbilical cable which connects the antenna to the processing equipment. The antenna transmits a radar impulse into the ground at a rate of 50 kHz while being towed continually along the survey route. A portion of each radar pulse is reflected from subsurface interfaces below the antenna and is received by the antenna which sends the information via cable to the processor and display recorder. The information is immediately displayed on the graphic recorder, thereby providing a real time geophysical representation of the water and soil section immediately beneath the radar antenna. Since the radar pulses are transmitted, received and sampled at a very high rate (16 pulses/second), the displayed data represents a continuous geophysical record of the survey line. At a speed over the ground of one mile per hour, a vertical radar scan of the subsurface is obtained every 4 inches along the horizontal trackline.

The ground penetrating radar system was operated according to the QA/QC procedures outlined in Appendix A. In addition to the field graphic record produced on the display recorder, a magnetic tape recording was obtained which was used for post-survey processing of the data.

The radar energy reflected from various subsurface materials depends on the contrast in electrical properties (conductivity and dielectric constants) of those materials. Soil electrical properties are dependent upon mineral constituents, density, and water content of the materials comprising a given soil type or subsurface unit. However, the classification of a given geologic unit (reflector) or subsurface anomaly on the radar record requires that some type of physical sample be taken.

2.4 Data Analysis and Interpretation

The magnetometer data were corrected for diurnal variations and contoured in total magnetic field and vertical gradient format for analysis and interpretation. Total magnetic field measurements allow mapping of local variations in the earth's magnetic field due to the nearby presence of ferrous materials. Vertical gradient measurements provide information representative of the differences in the local gradient of the earth's magnetic field created by nearby ferrous materials. Total magnetic field data is expressed in gammas while vertical gradient data is expressed in gammas/meter. The vertical gradient data were used to define the locations of magnetic anomalies which were more generally expressed on the total magnetic field presentation. An example of vertical gradient anomalies at a multiple buried drum area within the site is presented in Figure 3.

The EM-31 data were processed and contoured to reflect both the quadrature and the inphase components. The quadrature component or terrain conductivity is presented in units of millimhos/meter. Examples of EM-31 data from Site I are presented in Figures 3, 4, and 5. Figure 3 presents inphase component anomalies at a multiple buried drum site. Figure 4 presents general terrain conductivity conditions and the signature of a buried utility trench containing a steel pipe. Figure 5 highlights areas of anomalously high terrain conductivities which may represent ground-water contamination and/or areas of high metallic concentrations in the soil.

The Ground Penetrating Radar (GPR) data are recorded on facsimile paper in the form of a cross-sectional geophysical profile of the shallow soils along a given trackline. Several characteristic subsurface radar signatures or geophysical units were identified throughout the survey area. The geophysical interpretation of these characteristic radar signatures was based upon the general principals of geophysical facies analysis. Parameters which were considered in identifying the different subsurface geophysical features were: 1) reflection amplitude, 2) reflection continuity, 3) reflection configuration, 4) dominant reflection frequency, 5) geometry of the geophysical unit, 6) presence of diffractions, and 7) areal associations. An example of the geophysical signature of a buried 6-inch diameter pipe which was detected exiting Site I is presented in Figure 6.

Cultural interference masked the interpretation of the conductivity data and the magnetic data in portions of the site. The EM-31 data were most severely affected in the vicinity of the

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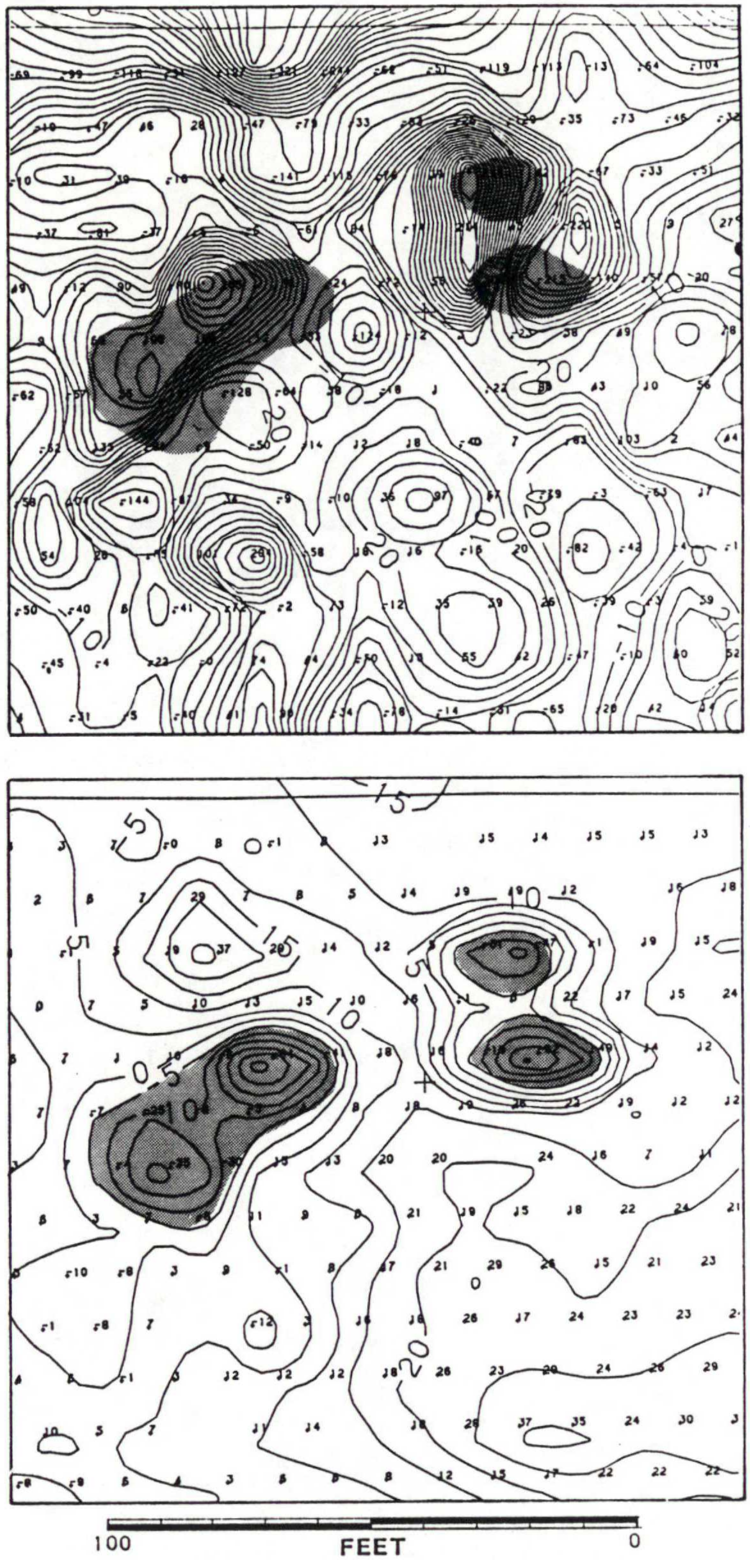
Vertical Magnetic Gradient Map. Contour Interval = 10 Gammas/meter.

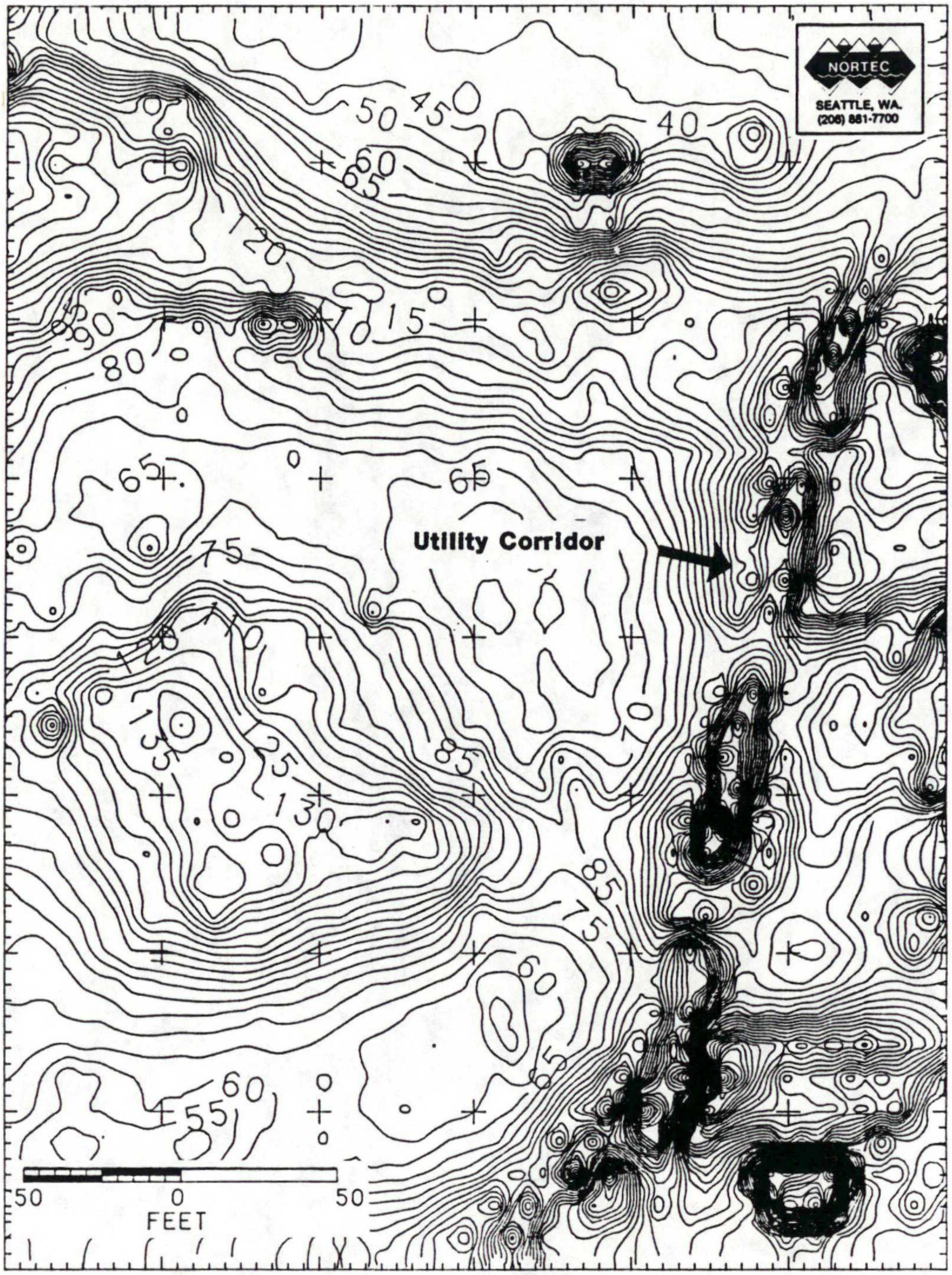
Buried Drum Site

EM-31 Inphase Component Map. Contour Interval = 5PPT.



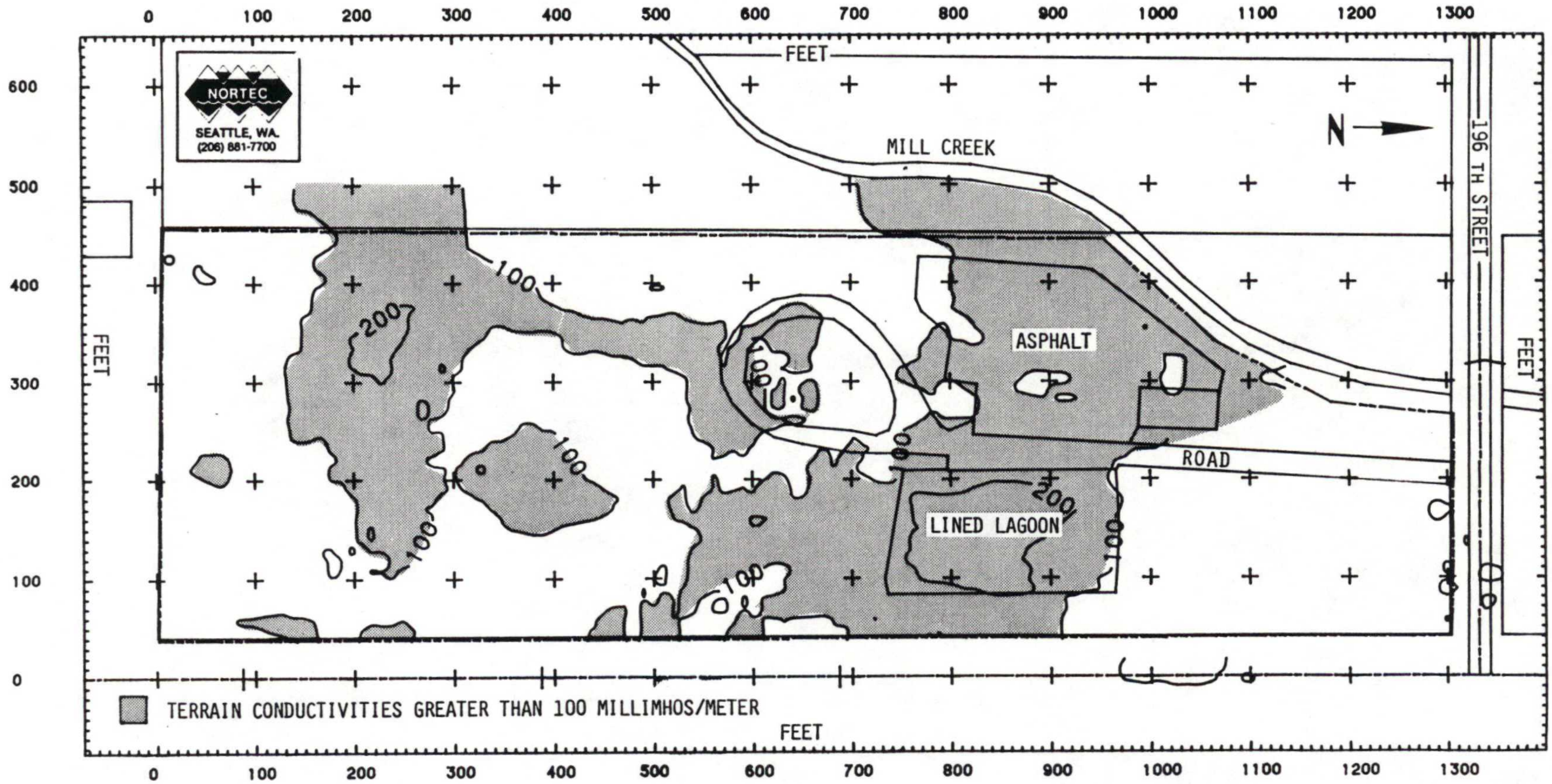
MAGNETOMETER/GRADIOMETER & EM-31 CONTOUR MAPS OF A MULTIPLE BURIED DRUM SITE

FIGURE 3



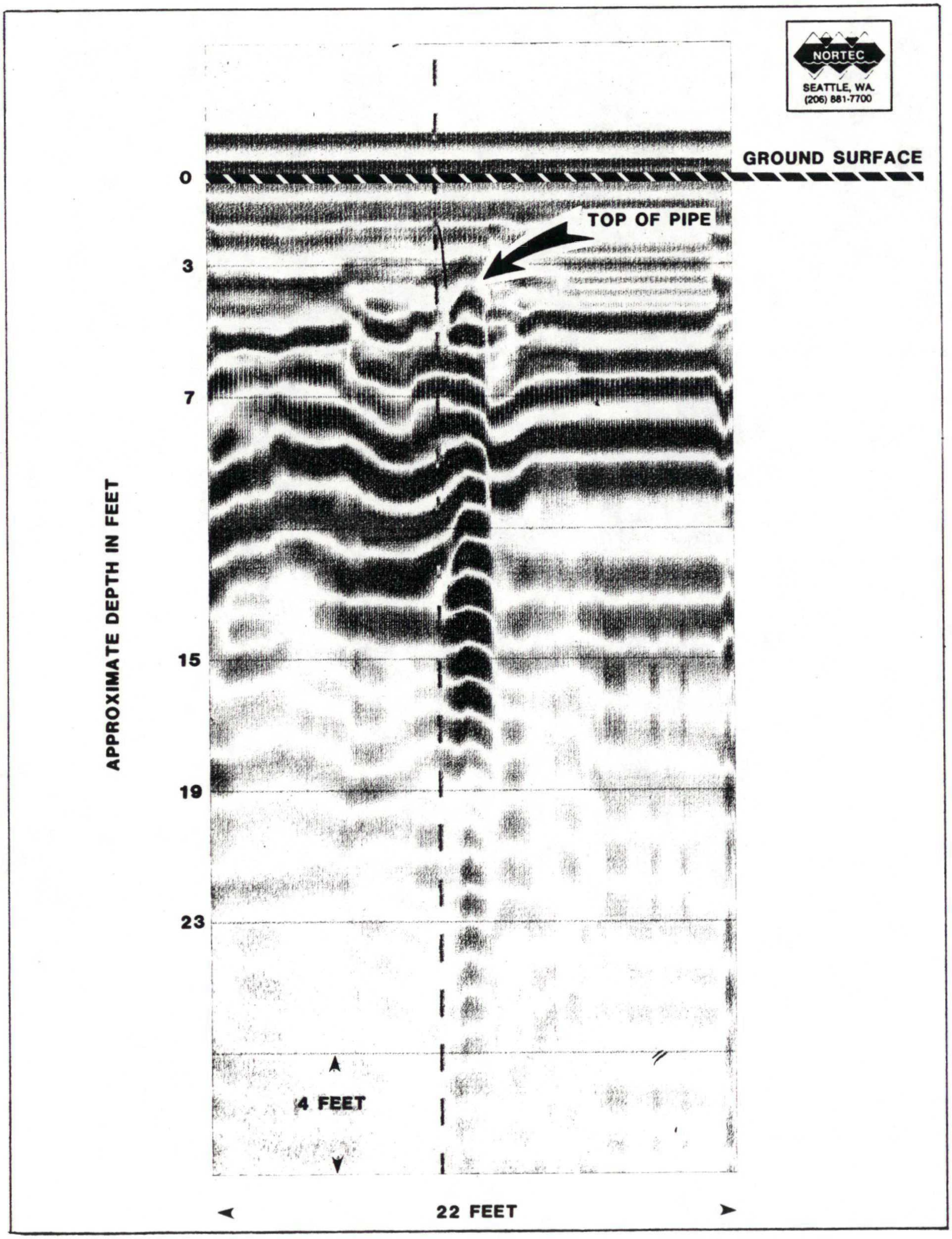
EM-31 TERRAIN CONDUCTIVITY SIGNATURE OF A BURIED UTILITY CORRIDOR

FIGURE 4



AREAS OF ANOMALOUS TERRAIN CONDUCTIVITIES

FIGURE 5



GROUND PENETRATING RADAR PROFILE ILLUSTRATING THE GEOPHYSICAL SIGNATURE OF A BURIED 6-INCH DIAMETER PIPE

FIGURE 6

fenceline surrounding the site, as well as in proximity to the trailers and other structures on the northern portion of Area I North. The magnetic data were also adversely affected by these structures, and were rendered nearly useless in a zone paralleling the eastern border of Area I by the field effects of a high voltage power line in this area.

Fortunately the radar system could be effectively operated in the vicinity of the fenceline and beneath the powerline, so that the choice of a suite of geophysical systems rather than just one technique permitted the acquisition of useful geophysical data over most of the site. The principal source of noise for the ground penetrating radar was the relatively high conductivity of the soil itself, which limited the depth penetration of the radar signal.

Identification of anomalous subsurface conditions was based on the conjunctive analysis of the EM-31 terrain conductivity and inphase component maps, the magnetic field intensity and vertical gradient maps, and the GPR profiles. Where possible, these geophysical anomalies were correlated with written or aerial photo documentations identifying historical land use on the site.

3.0 SURVEY RESULTS

3.1 General

The results of the analysis of the EM-31, the magnetometer, and the Ground Penetrating Radar surveys are summarized as composite geophysical anomalies in Table 1 and in Plate 1. Supporting geophysical information is provided in Plates 2 through 6.

3.2 Anomalous Subsurface Target Areas

A total of 39 anomalous regions were identified from the geophysical data. These regions are identified in Table 1 and Plate 1. Table 1 provides a general description of the geophysical character of the anomaly (i.e., EM, Magnetometer or Radar anomaly), a brief narrative of the nature of the anomalous region and an estimate of the possible nature of the anomaly.

Within many of the anomalous regions, specific subregions or target sites have been identified. These geophysical targets have also been listed in Table 1 and illustrated on Plate 1. No attempt has been made, within the scope of this investigation, to associate the geophysical targets with the nature of subsurface materials recovered during later excavations performed as a part of the overall program.

3.3 Anomalous Soil Conductivity Areas

A summary of the terrain conductivity data for the Western Processing property is presented in Plate 2 and Figure 5. While no terrain conductivity measurements were made over zones of natural soil at areas remote from the site, such measurements would be expected to range between 5 and 50 millimhos/meter in the silty sands characteristic of the Kent Valley.. Areas of terrain conductivity greater than 100 millimhos/meter have thus been considered anomalous on the Western Processing Site. Large areas of the site were determined to fall within this category. These areas of high terrain conductivity values may represent zones of ground-water contamination and/or sites of buried conductive wastes.

4.0 RECOMMENDATIONS

Although a substantial number of anomalous zones have been identified from the geophysical data set, a detailed comparison of the geophysical data with other information which is now known about the site should be undertaken to enhance the value of the geophysical results. This is particularly true with regard to analysis of the terrain conductivity data. Integration of the EM-31 data with the results of soil sampling and ground water monitoring may provide additional information on the distribution of toxic wastes or contaminated ground water on the site.

The terrain conductivity data which have been collected provide a valuable assessment of the areal distribution of soil conductivity across the site. The resolution of the vertical distribution of conductivity beneath the site is somewhat limited using a surface measurement technique which is a weighted average of the conductivity of the upper 20 feet of the soil profile. The use of a borehole conductivity probe is recommended for a detailed study of the vertical distribution of contaminants on the Western Processing site. Each of the PVC-lined monitoring wells on the site could be logged using this device, and the integration of this information with the surface EM-31 measurements would provide a more complete three-dimensional assessment of soil conductivity and toxic waste variations across the property. These measurements could be repeated at intervals throughout the remedial phase on the project to monitor the progress of the cleanup effort.

5.0 LIMITATIONS

Geophysical surveys performed as a part of this project may not successfully detect any or all subsurface objects or features present. Locations and depths of buried objects or subsurface features mapped as a result of this survey are the result of geophysical interpretations only, and should be considered as confirmed, actual, or accurate only where recovered by excavation or drilling.

TABLE 1

TABLE 1

GEOPHYSICAL ANOMALIES
WESTERN PROCESSING REMEDIAL ACTION SITE

AREA I

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	EM Inphase Component	Radar	Comments
801	X			X	Area of Magnetometer anomalies. No significant surface structures reported historically in this area. Graded areas reported in 1968 & 1972.
A	X				Magnetometer anomaly; primary target areas. Buried ferrous materials indicated.
802	X	X	X		Anomalous EM and Magnetometer region. Buried drums recovered in this area.
A	X				Magnetometer anomaly; primary target area. Buried ferrous materials indicated.
B		X	X		EM anomaly; buried conductive materials indicated.
C			X		Area of EM field disturbance.
D			X		Area of EM field disturbance, anomalous positive values.
803	X	X	X	X	Anomalous EM and Magnetometer region. Buried drums recovered.
A		X	X	X	EM anomaly; primary target area. Buried conductive materials indicated.
B		X	X	X	EM anomaly; primary target area. Buried conductive materials indicated.

TABLE 1
(Continued)

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	Inphase Component	Radar	Comments
803 C	X			X	Magnetometer anomaly; primary target area. Buried ferrous materials indicated.
804	X		X	X	Anomalous magnetometer and EM region. Radar targets detected.
A	X				Magnetometer anomaly; buried ferrous material indicated.
B			X		EM field disturbance; nature unknown. Anomalous positive values.
C			X	X	EM field disturbance; nature unknown. Anomalous positive values.
D	X				Magnetometer anomaly; buried ferrous materials indicated. Nature unknown.
E			X		EM field distrubance; nature unknown. Anomalous positive values.
F	X				Magnetometer anomaly; buried ferrous materials indicated. Nature unknown.
G			X		EM field disturbance; nature unkown. Anomalous positive values.
805	X			X	Magnetometer anomaly; buried ferrous materials indicated. Nature unknown.

TABLE 1
(Continued)

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	Inphase Component	Radar	Comments
806	X				Magnetometer anomaly; buried ferrous materials indicated. Nature unknown.
807	X			X	Anomalous Magnetometer region; nature unknown. Possibly a buried tank.
808	X				Magnetometer anomaly; nature unknown.
809	X				Magnetometer anomaly; possibly associated with ferrous materials disposed of in subsurface impoundments documented in this area between 1967 & 1969.
810	X	X			Area of Magnetometer and EM field disturbance; nature unknown.
811		X	X		EM Field Disturbance, nature unknown.
812	X	X	X	X	Anomalous Magnetometer and EM region. Original pre-1965 drainage course. Anomaly associated with ferrous materials, possibly drums, disposed of in this area. Subsurface radar diffractions.
A	X			X	Major Magnetic anomalies; primary target areas.
B			X		Area of EM field disturbance; target area, nature unknown. Anomalous positive values.

TABLE 1
(Continued)

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	EM Inphase Component	Radar	Comments
812					
C		X			Area of EM field disturbances; target area. Buried conductive materials indicated.
D		X			EM anomaly; target area. Buried conductive materials indicated.
813		X	X	X	Area of EM anomalies. Foundation of surface structure documented in this area between 1965 & 1982. Buried drums possible.
A		X	X	X	EM anomaly; primary target area. Buried conductive material indicated.
B	X	X	X		Magnetometer anomaly; primary target area. Buried ferrous materials indicated.
C		X	X	X	EM anomaly; primary target area. Buried conductive materials indicated.
814	X		X		Magnetometer anomaly and area of EM field disturbance; buried conductive material suggested. Primary target area, buried drums recovered.
A			X		Area of EM field disturbance; buried conductive materials indicated, nature unknown.
B	X				Magnetometer anamoly; buried ferrous material indicated.

TABLE 1
(Continued)

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	Inphase Component	Radar	Comments
815		X		X	Magnetometer anomaly; buried ferrous materials indicated. 6 inch steel pipe recovered which exits the site to the east. Terminus (eastern) estimated with radar.
816				X	Linear sequence of subsurface ground penetrating radar targets.
817	X				Magnetometer anomaly. Buried ferrous materials indicated, possibly debris from small structure reported on site between 1956 & 1983.
818	X	X	X	X	Area of magnetic anomalies and EM field disturbances. Possibly two separate features. Nature Unknown.
A			X	X	Area of EM field disturbance. Numerous subsurface radar targets; possibly pipes. Military base drainfield suggested. Feature may drain offsite to the west and Mill Creek.
B	X	X	X	X	Region of Magnetometer and EM anomalies. buried metallic targets indicated. Magnetic signature suggests vertical structure to depth. Possibly reinforced concrete.
C	X				Magnetometer anomaly; primary target area. Buried ferrous materials indicated.
D			X		EM anomaly; primary target area. Anomalous positive values; nature unknown.
E	X				Magnetometer anomaly; ferrous material indicated. Nature unknown.

TABLE 1
(Continued)

Anomaly Number	GEOPHYSICAL CHARACTER Magnetometer	EM Quadrature Component	EM Inphase Component	Radar	Comments
818					
F	X				Magnetometer anomaly; ferrous material indicated. Nature unknown.
819	X	X	X	X	Anomalous EM and radar region. Possibly utility or waste process line corridor. May have been installed for the fertilizer plant. Corridor may branch near eastern site boundary.
A		X	X		EM targets; buried metallic material indicated.
B	X				Magnetometer anomaly; nature unknown. Buried ferrous materials indicated.
C			X		Area of EM field disturbance. Secondary target area; anomalous positive values. Nature unknown.
D		X	X		Area of EM field disturbance; buried metallic material indicated. Building foundation or concrete pod observed at site.
E		X	X		Area of EM field disturbance; buried metallic material indicated. Possibly buried debris from small structure (pumphouse and sump) reported onsite between 1956 and 1983.
820					Unassigned

TABLE 1
(Continued)

Anomaly Number	GEOPHYSICAL CHARACTER Magnetometer	EM Quadrature Component	EM Inphase Component	Radar	Comments
821	X			X	Magnetometer anomaly and subsurface radar target detected; primary target area. Buried ferrous material indicated. Possibly remnants of storage tanks present onsite near this location or debris left in subsurface impoundment noted in this area in 1976.
822	X			X	Magnetometer anomaly; subsurface radar target detected, primary target area. Buried ferrous material indicated. Possibly remnants of storage tanks noted onsite near this location or debris left in subsurface impoundments documented near this area in 1976.
823	X	X		X	Magnetometer and EM anomaly; buried ferrous materials indicated. Subsurface radar targets detected. Possible remnants of storage or distilling tanks or military emplacements documented near this area.
A	X				Magnetometer anomaly; buried ferrous materials indicated. Nature unknown.
B			X	X	EM field disturbance and radar target. Buried metallic material indicated, nature unknown.
C		X			EM field disturbance low terrain conductivity values. Nature unknown.
D			X		EM field disturbance; buried metallic materials indicated, nature unknown.

TABLE 1
(Continued)

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	EM Inphase Component	Radar	Comments
824	X	X	X		Anomalous EM and Magnetometer region. Buried metallic materials indicated. Possibly debris left in subsurface impoundments documented in this area in 1974 & 1978.
A	X				Magnetometer anomaly; primary target area. Buried ferrous material indicated.
B	X				Magnetometer anomaly; buried ferrous material incicated, nature unknown.
C		X		X	EM anomaly; anomalous high positive values, nature unknown.
D	X				Magnetometer anomaly; buried ferrous materials indicated. Nature unknown.
825	X				Magnetometer anomaly; buried ferrous material indicated. Nature unknown.
826					Unassigned
827					Unassigned
828					Unassigned

TABLE 1
(Continued)

Anomaly Number	GEOPHYSICAL CHARACTER Magnetometer	EM Quadrature Component	EM Inphase Component	Radar	Comments
829	X	X			Area of Magnetometer, EM and subsurface radar anomalies. Buried ferrous materials indicated. Possibly debris associated with, or disposed of, in a subsurface impoundment or military emplacement documented near this site.
A	X			X	Magnetometer anomaly. Subsurface radar target detected; primary target area. Nature unknown, possible utility corridor.
B	X			X	Magnetometer anomaly. Subsurface radar target detected; buried ferrous material indicated. Nature unknown.
C	X				Magnetometer anomaly; primary target area. Buried ferrous material indicated. Nature unknown.
D		X			EM field disturbance. Low terrain conductivity values.
830	X				Magnetometer anomaly; primary target area. Buried ferrous material indicated. Possibly remnant of structure documented near this site between 1965 & 1983.
831	X	X	X	X	Anomalous Magnetometer and EM area. Subsurface radar target detected. Buried ferrous material indicated. Nature unknown. Possibly remnant of military gun emplacement or missile silo.
A	X				Magnetometer anomaly; primary target area. Buried ferrous material indicated.
B			X		Area of EM field disturbance; nature unknown. Buried metallic materials indicated.

TABLE 1
(Continued)

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	EM Inphase Component	Radar	Comments
831					
C		X			Area of EM field disturbance; secondary target. Nature unknown. Low terrain conductivity area.
832		X			Region of low terrain conductivity values. Nature unknown.
833					Unassigned
834					Unassigned
835					Unassigned
836		X	X		Unassigned
837	X	X		X	Anomalous region; Magnetometer, EM and Radar targets. Possibly a utility corridor and associated materials for the solvents recovery plant.
A	X			X	Magnetometer anomalies; primary target area. Buried ferrous materials indicated.
B	X	X			EM field distrubance; primary target area. Buried metallic materials suggested.
838	X	X	X	X	Anomalous Magnetometer, EM and Radar region. Possibly utility or waste process line corridor.

TABLE 1
(Continued)

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	EM Inphase Component	Radar	Comments
838					
A	X			X	Magnetometer anomalies, buried ferrous materials indicated.
B		X			EM anomalies; buried conductive materials indicated.
C			X		EM anomaly; buried conductive material indicated. Nature unknown.
D			X		Area of EM field distrubance; possible utility or waste process line corridor.
839	X	X	X	X	Anomalous region. Magnetometer, EM, and Radar anomalies. Known area of large subsurface tank and surface concrete pad. Additional piping or subsurface support materials suggested.
A			X		Area of EM field disturbance; tank area. Buried conductive material suggested.
B	X				Magnetometer anomaly; tank area. Conductive materials indicated.
C			X		EM anomaly of unknown nature. Anomalous positive values.
D			X		EM anomaly of unknown nature.
E	X				Magnetometer anomaly of unknown nature. Buried ferrous materials indicated.
F	X	X			Anomalous Magnetometer area. Concrete pad exposed at surface.

TABLE 1
(Continued)

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	Inphase Component	Radar	Comments
839					
G	X				Magnetometer target associated with surface concrete pad.
H	X				Magnetometer target; nature unknown.
I		X	X		EM target associated with surface concrete pad.
840					Unassigned
841	X	X	X	X	Anomalous region. EM, Magnetometer and Radar anomalies; nature unknown. Possibly materials associated with, or disposed of, in south end of solids pond documented in this area between 1974 and 1982.
A	X				Magnetometer anomaly; ferrous material indicated. Nature unknown.
B	X				Magnetometer anomaly; primary target area. Subsurface ferrous materials indicated.
C			X		EM field disturbance; low terrain conductivity values.
D	X				Magnetometer anomaly; buried ferrous materials indicated.
E			X		EM field disturbance; anomalous positive values.
F			X		EM field disturbance; anomalous positive values.
G			X		Magnetometer anomaly; buried ferrous materials indicated. Nature unknown.

TABLE 1
(Continued)

Anomaly Number	GEOPHYSICAL CHARACTER Magnetometer	EM Quadrature Component	EM Inphase Component	Radar	Comments
841					
H	X				Magnetometer anomaly; primary target area. Buried ferrous material indicated. Nature unknown.
I			X		EM field disturbance; anomalous positive values.
J	X				Magnetometer anomaly; buried ferrous material indicated. Nature unknown.
K			X	X	EM and Radar anomaly; disturbed soil area with subsurface targets. Nature unknown.
842				X	Radar anomaly; disturbed soil zone with subsurface targets. Nature unknown.
843	X	X	X	X	Anomalous region; Magnetometer, EM, and Radar features. Concrete pad at surface at west end. Ferrous materials indicated.
A		X	X		EM anomaly; buried conductive materials indicated. Concrete pad visible.
B	X				Magnetometer anomaly; primary target area. Ferrous material indicated. Nature unknown.
C		X			Magnetometer anomaly; ferrous materials indicated. Nature unknown.
D				X	Radar anomaly; disturbed soil zone with multiple targets. Possibly associated with subsurface impoundment documented in this area between 1969 and 1977. Utilities or waste process line corridor possible.

TABLE 1
(Continued)

Anomaly Number	Magnetometer	GEOPHYSICAL CHARACTER EM Quadrature Component	EM Inphase Component	Radar	Comments
844			X		Area of EM field disturbance; possibly remnant of subsurface storage pond documented in this area between 1967 and 1972. Anomalous high positive values.
845				X	Radar anomaly; disturbed soil zone. Filled trench suspected.
846	X			X	Anomalous Magnetometer area; nature unknown. Buried ferrous materials indicated.
A	X		X		Magnetometer and EM anomaly; buried ferrous material indicated.
B	X		X		Magnetometer anomaly; buried ferrous material indicated.
C	X		X		Magnetometer anomaly; buried ferrous material indicated.
847		X	X		EM field disturbance, nature unknown; possible utility corridor.
848					Unassigned
849				X	Anomalous radar target; nature unknown.
850		X	X		EM field disturbance; possible utility corridor. Nature unknown.

TABLE 1
(Continued)

Anomaly Number	GEOPHYSICAL CHARACTER Magnetometer	EM Quadrature Component	EM Inphase Component	Radar	Comments
851			X		Area of EM field disturbance; nature unknown. Anomalous high positive values.

APPENDIX A

TECHNICAL PROCEDURES DOCUMENT

Ground Penetrating Radar

1.0 PURPOSE

A geophysical survey using several systems, including ground penetrating radar will be conducted at the Western Processing Site. The purpose of this survey is to acquire information on the subsurface conditions at the site and identify areas that have been contaminated as a result of past activities associated with industrial waste processing and recycling. Of particular interest is the location of buried drums, tanks, utilities, and process lines within the site and the locations of all abandoned and active utilities, process lines, or other pipes leaving the site and crossing into or ending on adjacent properties.

2.0 APPLICABILITY

This technical procedure is applicable to all persons having access to ground penetrating radar (GPR) systems, and who are trained in GPR operations and record interpretation. Ground penetrating radar is applicable to any subsurface profiling where sufficient differences in electrical properties (conductivity and dielectric constants) exist.

3.0 DEFINITIONS

None.

4.0 REFERENCES

4.1 R.M. Morey and W.S. Harrington, Jr., "Feasibility Study of Electromagnetic Subsurface Profiling", U.S. Environmental Protection Agency, Washington, D.C., EPA-R2-72-082, October 1972.

4.2 C.L. Bertram, R.M. Morey, and S.S. Sandler, "Feasibility Study for Rapid Evaluation of Airfield Pavements", Air Force Weapons Laboratory Report AFWL-TR-71-17, June 1974.

4.3 R.M. Morey, "Application of Downward Looking Impulse Radar", Proc. of 13th Annual Canadian Hydrographic Conference, (Canada Centre for Inland Waters, Burlington, Ont.) pp. 83-99, March 1974.

4.4 M.B. Kraichmann, Handbook of Electromagnetic Propagation in Conducting Media, Washington, D.C., U.S. Government Printing Office. (Document NAVMAT, p. 2032) 1970.

4.5 J.R. Wait, (ed.), Electromagnetic Probing in Geophysics, The Goldem Press, Boulder, Co. 1971.

4.6 A.R. Von Hippel, Dielectric Materials and Applications, John Wiley & Sons, New York, 1954.

5.0 DISCUSSION

None.

6.0 RESPONSIBILITY

All individuals engaged in conducting geophysical survey with ground penetrating radar are responsible for compliance with this procedure.

7.0 EQUIPMENT AND MATERIALS

- 120 MHz ground penetrating radar antennas
- Signal processing unit
- Graphic recorder
- Analog tape recorder
- Electrical/mechanical umbilical cable
- Power supply unit

8.0 PROCEDURE

8.1 For reference purposes, the survey site has been divided into two (2) primary areas. Area I south and adjacent properties, and Area I north and adjacent properties. Area I south will be surveyed first.

8.2 Within each area, planned radar profiles will be as specified in the detailed geophysical survey plan. Additional radar tracklines will be run as required to further delineate subsurface geophysical anomalies or track buried utilities, or process waste lines to their source or terminus.

8.3 Approximate horizontal control for the radar profile lines will be determined from established surveyed control points on 75 foot centers using a surveyor's tape. Control points will be geodetically surveyed for x and y coordinates. Positions along a given profile line will be measured with a surveyor's tape and marked at ten foot intervals. A fiducial will be placed on the radargram corresponding with each of these marks.

8.4 The ground penetrating radar system antenna will be towed along the ground; the processing and display equipment shall be contained in a small cart or truck; and an electrical/mechanical umbilical cable will be used to connect the antenna to the processing equipment. The antenna will transmit a radar impulse into the ground at a rate of 16 pulses/sec. while being towed continually along the survey route. A near constant rate of towing will be maintained, if possible, between reference marks. Impulse energy reflected from subsurface interfaces will be received by the GPR antenna, converted and enhanced by the signal processor and presented on a graphic facsimile recorder. The intensity of reflected radar energy from subsurface materials interfaces is dependent upon the relative difference in the electrical properties of adjacent materials (conductivity and dielectric constants). These electrical properties are dependent upon the materials water content, and mineral and chemical constituents.

8.5 An electronic timing signal is used for calibration of the record. The sweep rate of the recorder requires calibration because it represents the depth of the reflecting targets. The timing signal calibration will be performed at least once daily or at least once within each survey area (whichever is oftener), and when any change in instrument sweep rate is made during the course of a survey. The transmitted signal strength is continuously recorded and printed on the graphic display record for data reduction and interpretation.

8.6 Additional system calibrations directly related to soils depth or burial calculations may be performed during the survey in areas where known soil depths to detected subsurface features (such as buried utilities or soil horizons from borehole logs) are available. For areas where this information is not available, published tables will be referenced for average materials corrections for estimation of depths of burial.

8.7 GPR reflection information displayed on the graphic recorder, will produce a vertical record section of the subsurface soils, water table and buried objects along the survey route, which will then be interpreted and reduced to plan view or cross-sectional format using control data established during the field survey.

8.8 During the radar survey, significant subsurface anomalies detected will be staked with a color coded system. Stakes will be numbered and dated. Field entries will be made in a staking log documenting line number, control point or location time of observation, and field interpretation of the anomaly. Daily plan view maps of the staking activity will be prepared and revised as appropriate as survey progresses. Following completion of the initial survey, additional radar tracklines may be required to assist in tracking or identifying subsurface geophysical anomalies identified with other geophysical systems or to track suspected subsurface utilities or abandoned or active waste process lines to their source or terminus.

8.9 Plan view maps prepared for each survey area will show the survey coverage and the estimated location or extent of anomalous subsurface features. These features may include discrete objects such as barrels, pipes, trenches, voids, contaminant plumes and other natural or unnatural soil zones. Cross-section profiles will be prepared where needed to clarify subsurface conditions such as the geomorphology of a buried waste disposal impoundment. Final survey results may not successfully delineate any or all subsurface objects or features present. Locations and depths of buried objects or subsurface features mapped as a result of these surveys will be the result of geophysical interpretation only, and should be considered as confirmed, actual or accurate only where recovered by excavation or drilling.

APPENDIX B

TECHNICAL PROCEDURES DOCUMENT

Conducting Eletromagnetic Surveys

CONDUCTING ELECTROMAGNETICS SURVEYS

1.0 PURPOSE

A geophysical survey using several systems including electromagnetics (EM) will be conducted at the Western Processing Site. The purpose of this survey is to acquire information on the subsurface conditions at the site and identify areas that have been contaminated as a result of past activities associated with industrial waste processing and recycling. Of particular interest is the location of buried drums, tanks, utilities, and process lines within the site and the locations of all abandoned and active utilities, process lines, or other pipes leaving the site and crossing into or ending on adjacent properties.

2.0 APPLICABILITY

This technical procedure is applicable to all persons who have access to electromagnetics (EM) equipment and who are trained in EM operation and data interpretation. Electromagnetics survey is applicable to any geophysical investigation where a sufficient difference in subsurface conductivity exists.

3.0 DEFINITIONS

None.

4.0 REFERENCES

4.1 Geonics Limited, Operating Manual for EM31 Non-Contacting Terrain Conductivity Meter, June 1984.

4.2 Benson, R., Glaccum, R. and M. Noel, "Geophysical Techniques for Sensing Buried Wastes and Waste Migration", U.S. Environmental Protection Agency, Las Vegas, Nevada, 1982.

4.3 McNeill, J.D., "Electromagnetic Resistivity Mapping of Contaminant Plumes", Proceedings of the National Conference on Management of Uncontrolled Hazardous Waste Sites, Silver Springs, MD., 1982.

4.4 Koerner, R., Lord, A., Tyagi, S., and J. Brugger, "Use of NDT Methods to Detect Buried Containers in Saturated Silty Clay Soil", Proceedings of the National Conference on Management of Uncontrolled Hazardous Waste Sites, Silver Springs, MD. 1982.

4.5 Slaine, D., and J. Greenhouse, "Case Studies of Geophysical Contaminant Mapping at Several Waste Disposal Sites", Proceedings of the Second National Symposium, on Aquifer Restoration and Ground Water Monitoring, Columbus, Ohio, May 1982.

4.6 Kraichmann, M.B., "Handbook of Electromagnetic Propagation in Conducting Media", Washington, D.C., U.S. Government Printing Office, 1970.

5.0 DISCUSSION

None

6.0 RESPONSIBILITY

All individuals engaged in conducting geophysical survey with electromagnetics (EM) equipment are responsible for compliance with this procedure.

7.0 EQUIPMENT AND MATERIALS

- Self-contained dipole transmitter
- Self-contained dipole receiver
- Power supply
- System control unit
- Digital data logger

8.0 PROCEDURE

8.1 For reference purposes, the survey site has been divided into two (2) primary areas, Area I south and adjacent properties and Area I north and adjacent properties. Area I south will be surveyed first.

8.2 Within each area, EM measurements will be acquired as specified in the detailed geophysical survey plan. Additional EM data will be acquired as required to further delineate subsurface geophysical anomalies or to track buried utilities, or process waste lines to their source or terminus.

8.3 Within each area approximate horizontal control for the EM survey will be determined from established survey control points on 75 foot centers using a surveyor's tape. Control points will be geodetically surveyed for x and y coordinates. Positions along a given survey line will be measured with a surveyor's tape and marked at 10 foot intervals. A station grid number will be placed on the EM recording which corresponds with each ten foot EM sounding.

8.4 The EM system shall be operated along each survey line in a continuous operating mode, however, discrete measurements will be obtained at preselected stations located on 10 foot centers. Depth penetration will be on the order of 6 meters. Because the instrument has a time constant of about one second, the operator should adjust his walking speed accordingly to obtain greatest accuracy. The operator should note the continuous variation of the readings as the survey grid is traversed to more closely isolate the boundaries of encountered anomalies. Discrete station readings will be made in both the quadrature phase and inphase modes. The former being a measurement of the shallow subsurface conductivity and the latter providing a sensitive means of subsurface metal detection.

8.5 The EM operator must be capable of demonstrating repeatability of readings at any one station. Three replicate readings should be taken at the beginning of each line as a check of data repeatability. These data will be logged in the daily field notes for reference in post survey processing or onsite corrective action where required.

Differences in the carrying height of the dipole receiver and transmitter off the ground can affect the repeatability of station measurements. Care should be taken to standardize the receiver/transmitter height. All changes in this height during survey should be noted in the field log.

Operator heading errors are also of concern. Three replicate readings at the beginning of each field day for each approximate survey heading utilized in that day's survey will be noted in the field log for reference during post survey data processing or for corrective action on site where results warrant. These measurements will be made at a representative site selected specifically for this purpose.

Rain may have a significant effect on the EM readings. When survey is performed during or after a rainstorm, comparisons of the daily repeatability tests for operator headings should be consulted in the data reduction phase for relative corrections due to these effects. Additional repeatability tests should be made in the field at the designated test site if rain occurs during a field survey day.

8.6 The selected EM system has been factory calibrated to read properly. Once calibrated, the stability of the system over extended periods of operation and use is well documented. Prior to onsite survey however, the system will be subject to absolute calibration and null calibration and a site nearby to the survey area will be selected for daily reference checks of system stability. A record will be kept of all initial and daily calibration checks.

8.7 The EM sounding information acquired in the field will record a spot measurement of electrical conductivity of the subsurface materials to a depth of approximately 6 meters below each discrete station as well as a measurement indicative of the presence of metal. This information is intended to assist in defining those areas of the site that contain conductive materials that differ from the average background conductivity as well as buried tanks, pipes, and drums.

8.8 During the EM survey, significant subsurface anomalies detected will be field staked with a color coded system. Stakes will be numbered and dated. Field entries will be made in a staking log documenting line number, control point or location, time of observation, and field interpretation of the anomaly. Daily plan view maps of the staking activity will be prepared and revised where appropriate as the survey progresses. Following completion of the initial survey, additional EM measurements may be required to assist in tracking or delineating subsurface geophysical anomalies identified with other geophysical systems or to track suspected subsurface utilities or abandoned or active waste process lines to their source or terminus.

8.9 Plan view maps prepared for each survey area will show the survey coverage and the estimated location or extent of anomalous subsurface features. These features may include discrete objects such as barrels, pipes, trenches, contaminant plumes, or other natural or unnatural soil zones. Cross-sectional profiles, contour maps, or other graphic techniques will be employed where needed to clarify subsurface conditions.

Final survey results will ultimately be integrated with the results of other systems and a composite geophysical anomaly map prepared. Final survey results may not successfully delineate any or all subsurface objects or features present. Locations and depths of buried objects or subsurface features mapped as a result of these surveys will be the result of geophysical interpretation only and should be considered as confirmed, actual or accurate only where recovered by excavation or drilling.

APPENDIX C

TECHNICAL PROCEDURES DOCUMENT

Conducting a Magnetic Gradient Survey

APPENDIX C

TECHNICAL PROCEDURES DOCUMENT

CONDUCTING A MAGNETIC GRADIENT SURVEY (INCLUDING A TOTAL FIELD COMPILATION)

1.0 PURPOSE

A geophysical survey using several systems including a portable field magnetometer/gradiometer will be conducted at the Western Processing Site. The purpose of this survey is to acquire information on the subsurface conditions at the site and identify areas that have been contaminated as a result of past activities associated with industrial waste processing and recycling. Of particular interest is the location of buried drums, tanks, utilities, and process lines within the site and the locations of all abandoned and active utilities, process lines, or other pipes leaving the site and crossing into, or ending on, adjacent properties.

2.0 APPLICABILITY

This technical procedure is applicable to all persons having access to portable magnetometer/gradiometer equipment and who are trained in system operation and data interpretation. Magnetic surveys are applicable to any geophysical investigation where the subsurface distribution of ferrous materials is sufficient to create a measurable change in the intensity of the earth's magnetic field. Variations in this field may be caused by the natural distribution of iron oxides within the soil and rock or by the presence of buried iron or steel objects such as drums, tanks, or pipes.

3.0 DEFINITIONS

None.

4.0 REFERENCES

4.1 EDA Instruments, Inc., Operation Manual for Omni IV Tie-Line Magnetometer, 1985.

4.2 Benson, R., Glaccum, R. and M. Noel. Geophysical Techniques for Sensing Buried Wastes and Waste Migration. U.S. Environmental Protection Agency, Las Vegas, Nevada, 1982.

4.3 Evans, R. Currently Available Geophysical Methods for Use in Hazardous Waste Site Investigation. U.S. Environmental Protection AGency, Las Vegas, Nevada.

4.4 Tyagi, S., Lord, A., and R. Koerner. Use of a Proton Precession Magnetometer to Detect Buried Drums in Sandy Soil. Journal of Hazardous Materials, Vol. 8, 1983.

4.5 Slaine, D. and J. Greenhouse. Case Studies of Geophysical Contaminant Mapping at Several Waste Disposal Sites. Proceedings of the Second National Symposium of Aquifer Restoration and Ground Water Monitoring, Columbus, Ohio, May 1982.

5.0 DISCUSSION

None.

6.0 RESPONSIBILITY

All individuals engaged in conducting geophysical survey with portable field magnetometer/gradiometer equipment are responsible for compliance with this procedure.

7.0 EQUIPMENT AND MATERIALS

- Instrument console with memory (data logger)
- Gradient sensors
- Pole assembly
- Battery cartridge
- Battery charger

8.0 PROCEDURE

8.1 For reference purposes, the survey site has been divided into two (2) primary areas, Area I south and adjacent properties and Area I north and adjacent properties. Area I south will be surveyed first.

8.2 Within each area, Magnetometer measurements (vertical gradient and total field compilation) will be acquired as specified in the detailed geophysical survey plan. Additional magnetometer data will be acquired as required to further delineate subsurface geophysical anomalies or to track buried utilities, or process waste lines to their source or terminus.

8.3 Within each area approximate horizontal control for the magnetometer survey will be determined from established survey control points on 75 foot centers using a surveyor's tape. Control points will be geodetically surveyed for x and y coordinates. Positions along a given survey line will be measured with a surveyor's tape marked at 10 foot intervals. An event mark will be placed on the magnetometer recordings which corresponds with each set of magnetometer readings.

8.4 The magnetometer system shall be operated along each survey line so that discrete measurements are obtained in the system memory at preselected stations located on 10 foot centers. Vertical separation of the gradiometer sensors will be 0.5 meters. All field measurements will be referenced to a constant magnetic datum acquired at a magnetometer base station established nearby. Diurnal variations in the earth's magnetic field will be removed from the field data during the data reduction and processing phase using the base station information.

8.5 The minimum sample time for the magnetometer is 4 seconds and the acquisition of data at each station should be planned to include a minimum occupancy time at each station in excess of this time period.

8.6 Excess noise can be produced in the data by carrying the magnetic sensors too close to the ground, due to local variations in the magnetic characteristics of the soil. Raising the sensors 3 to 6 feet off the ground can reduce or eliminate this noise but at the same time may appreciably reduce subsurface target signals. Therefore, a proper balance must be attained between instrument sensitivity and operating height as the survey progresses. Care should be taken to standardize magnetometer sensor height. All changes in sensor height should be noted in the field log.

Noise interference from personal effects and clothing may also create a problem. The operator should attempt to eliminate all ferrous material from his person. Steel-toed boots and some respirators are common sources of noise. If these items are required by the health and safety conditions of the job site, their effects may be minimized by keeping the sensors as far from the operator as possible.

8.7 The magnetometer must be capable of demonstration repeatability of magnetic readings at any one station. Three replicate readings should be taken at the beginning of each line as a check of data repeatability. These data will be logged in the daily field notes for reference in post survey processing or onsite corrective action where required.

Operator heading errors are also of concern. Three replicate readings at the beginning of each field day for each approximate survey heading utilized in that day's survey will be noted in the field log for reference during post survey data processing or for corrective action onsite where results warrant. These measurements will be made at a representative site selected specifically for this purpose.

8.8 Proton magnetometer sensors are inherently calibrated, as their operation is based on nuclear precession; only their crystal controlled counters may require occasional calibration. The selected magnetometer provides a built-in test capability which confirms the validity of field measurements, data acquisition and record processing. The following field tests will be implemented each day: 1) a total field test, 2) and error calculation test, and 3) a software diagnostics test.

8.9 During the magnetometer survey, significant subsurface anomalies detected will be staked with a color coded system. Stakes will be numbered and dated. Field entries will be made in a staking log documenting line number, control point or location, time of observation, and field interpretation of the anomaly. Daily plan view maps of the field staking activity will be prepared and revised where appropriate as the survey progresses. Following completion of the initial survey, additional magnetometer data may be required to assist in tracking or delineating subsurface geophysical anomalies identified with other geophysical systems or to track suspected subsurface utilities or waste process lines to their source or terminus.

8.10 Plan view maps prepared for each survey area will show the survey coverage and the estimated location or extent of anomalous subsurface features. These features may include discrete objects such as barrels, pipes, subsurface tanks or other ferrous objects. Areas having negative magnetic gradients not associated with a corresponding positive gradient may be indicative of either magnetic objects or non-native magnetic materials such as metal-rich sludges.

Cross-sectional profiles, contour maps, or other graphic techniques will be employed where needed to clarify subsurface anomalies. Final survey results will ultimately be integrated with the results of other systems and a composite geophysical anomaly map prepared. Final survey results may not delineate all subsurface objects or features present. Locations and depths of buried objects or subsurface features mapped as a result of these surveys will be the result of geophysical interpretation only and should be considered as confirmed, actual or accurate only where recovered by excavation or drilling.

Investigation Drawings

PLATE 1

Composite Geophysical Anomaly Map
Remedial Action Areas I, II, III, V,
IX & X

TARGET SHEET

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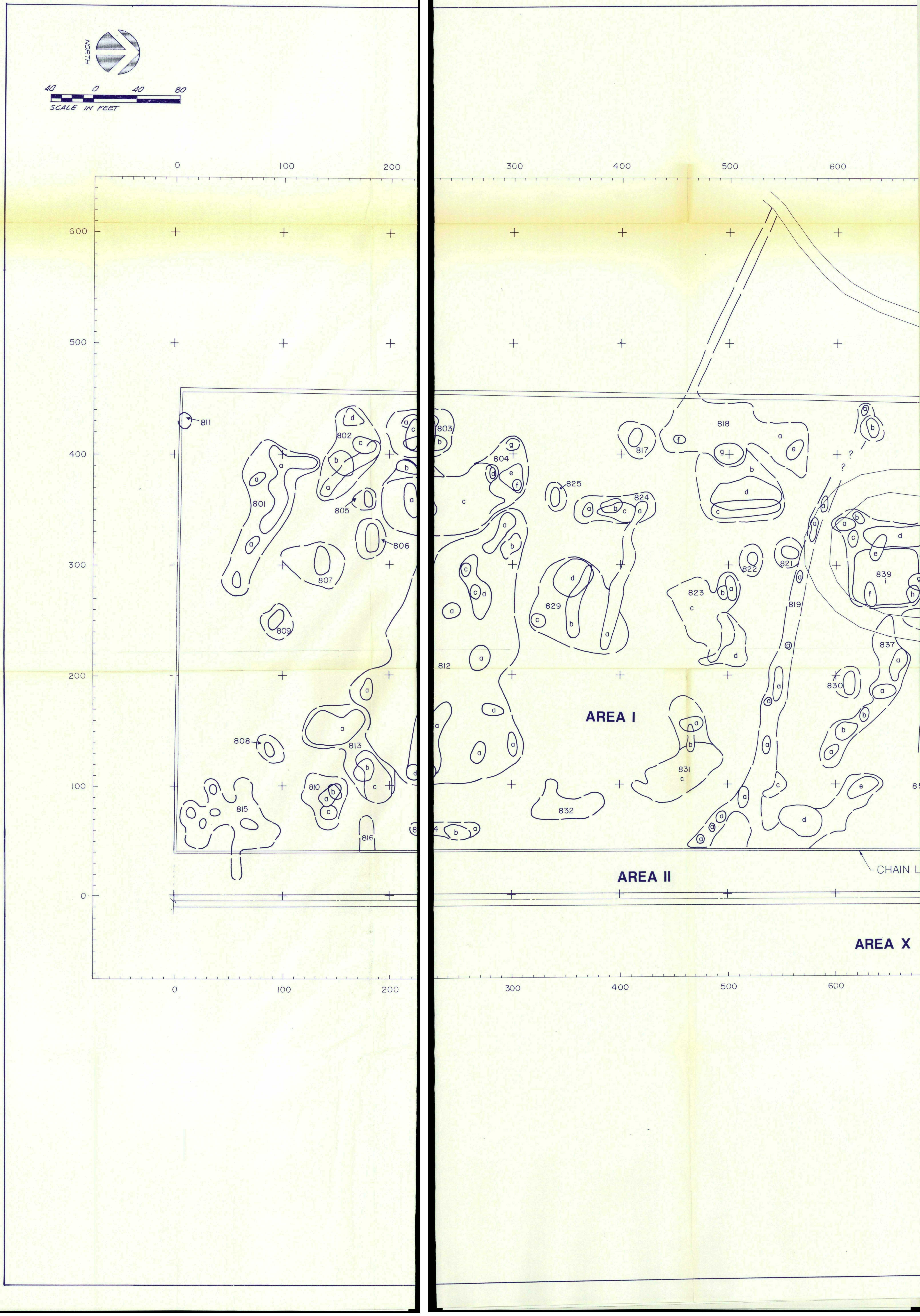
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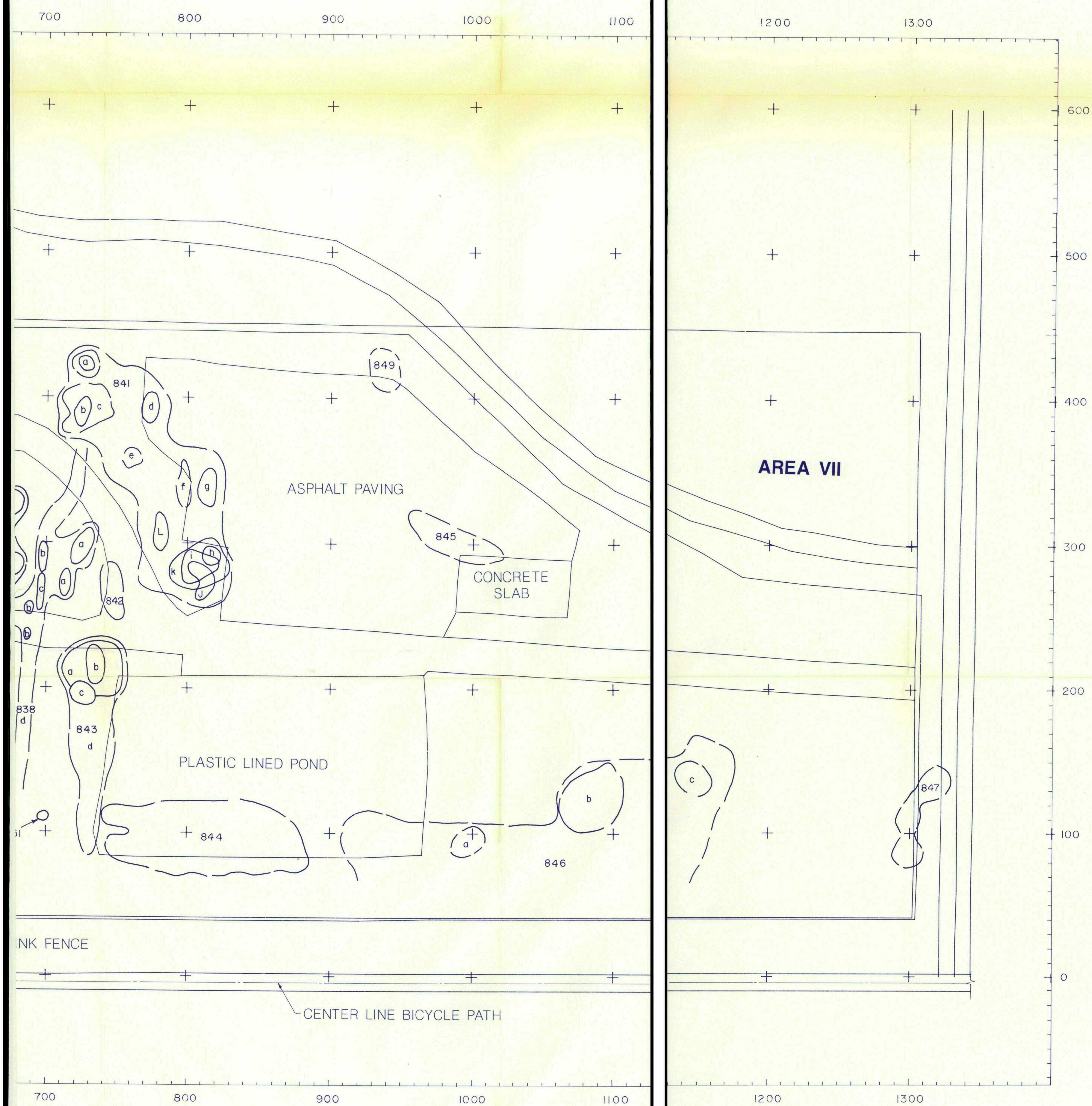

HDR Infrastructure, Inc.
A Centerra Company

NORTEC

Geophysical Survey and Site Sampling Investigation

Western Processing Site
Kent, Washington
1987

Composite Geophysical Anomaly Map

Project Number	44-01-02
Date	March 6, 1987
Project Manager	Ken Lepic
Design	Ken Scheffler
Architectural	
Structural	
Mechanical	
Electrical	
Drawn By	Tony Petrillo
Revisions	

PLATE 1

TARGET SHEET

Document ID PART OF 1518509
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- ☐ Cassette*
- ☑ Oversize.

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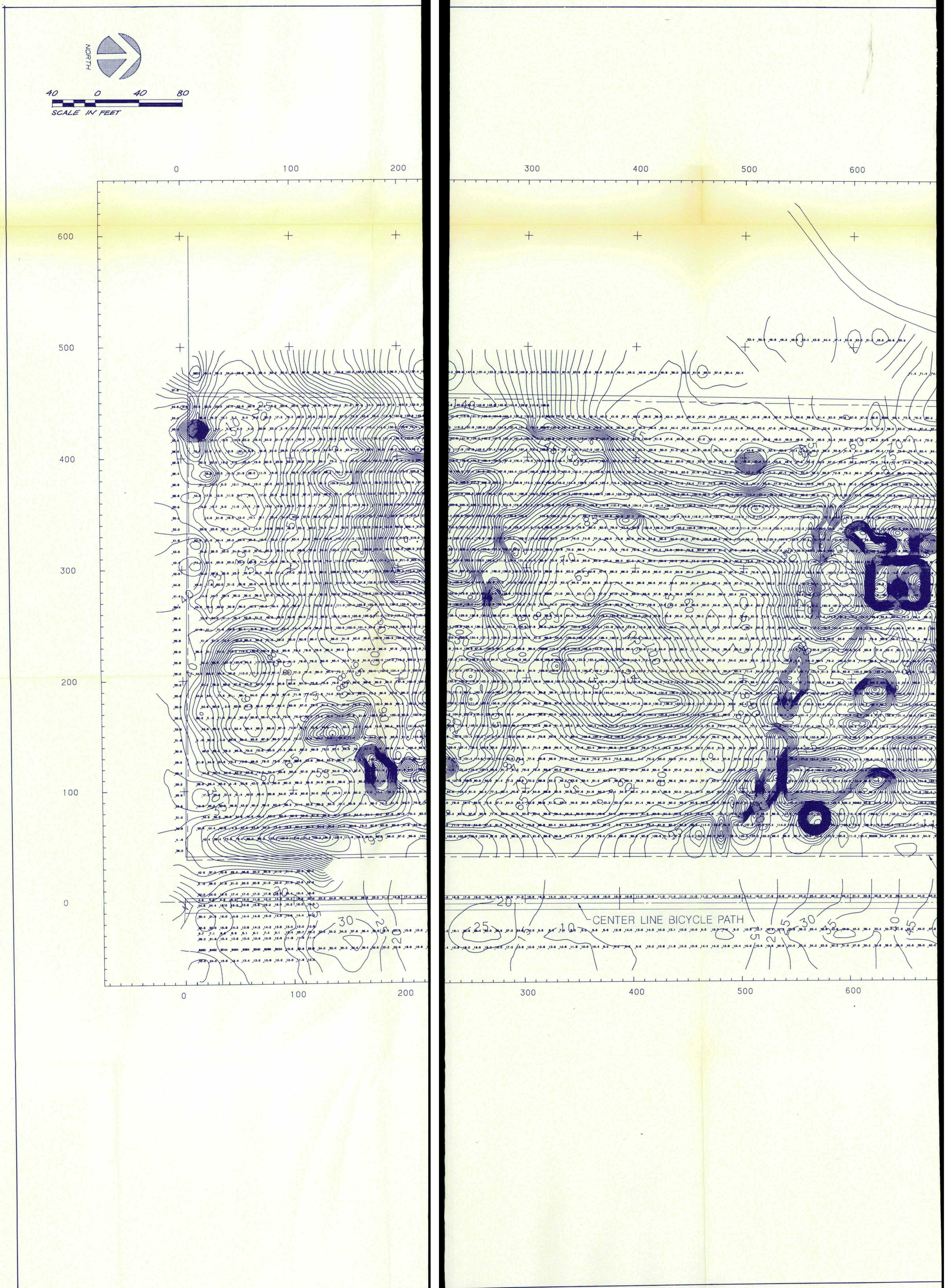
PLATE 2

Electromagnetic Terrain Conductivity
Map
Remedial Action Areas I, II, III, V,
IX & X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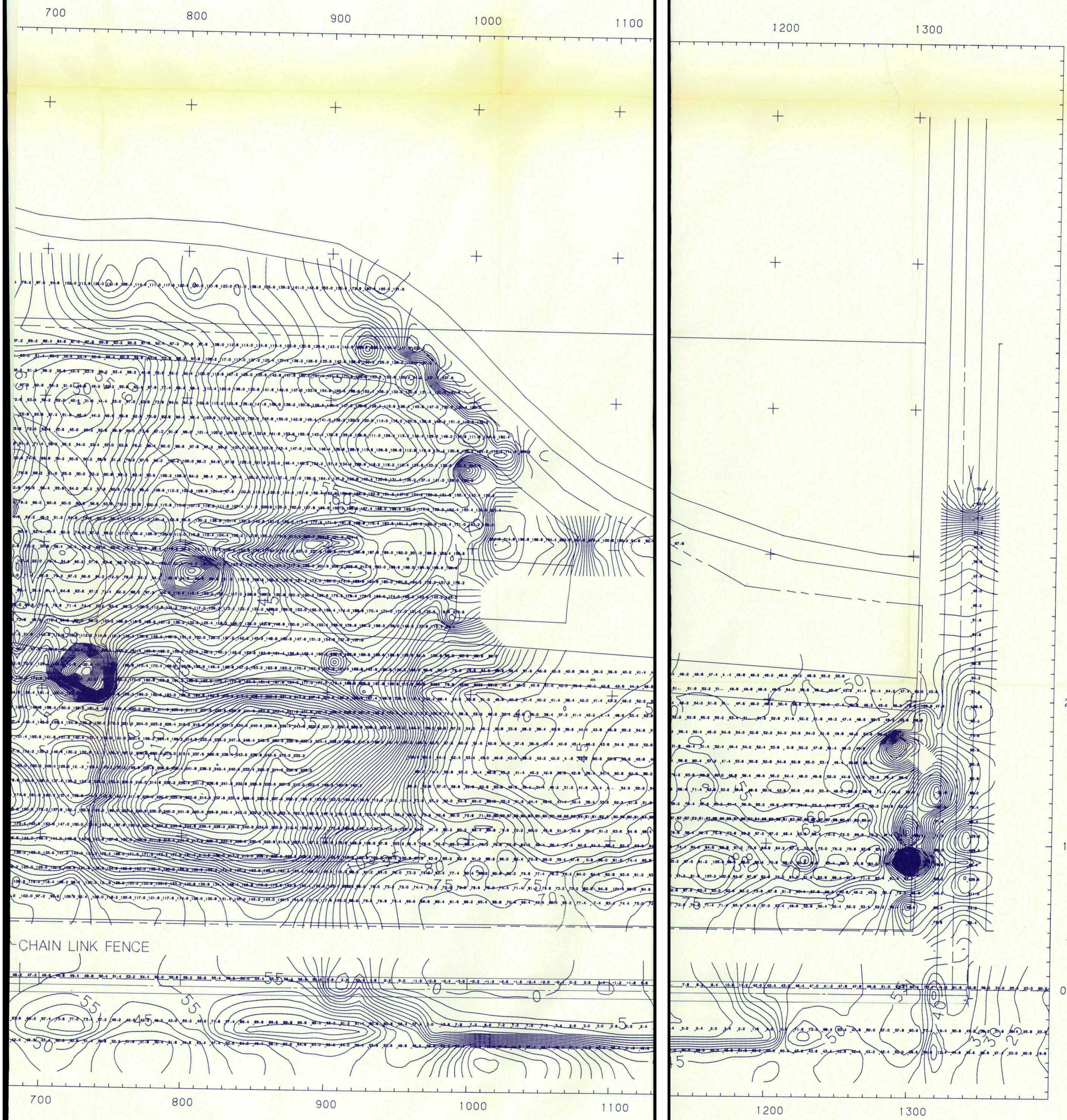

HDR Infrastructure, Inc.
A Centerra Company

NORTEC

Geophysical Survey and Site Sampling Investigation

Western Processing Site
Kent, Washington
1987

E.M. Conductivity Map

Project Number	44-01-02
Date	March 6, 1987
Project Manager	Ken Lepic
Design	Ken Scheffler
Architectural	
Structural	
Mechanical	
Electrical	
Drawn By	Tony Petrillo
Revisions	

PLATE 2

PLATE 3

Electromagnetic Inphase Component Map
Remedial Action Areas I, II, III, V,
IX & X

TARGET SHEET

Document ID PART OF 1518509

Site File:

Folder:

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3 of 6.

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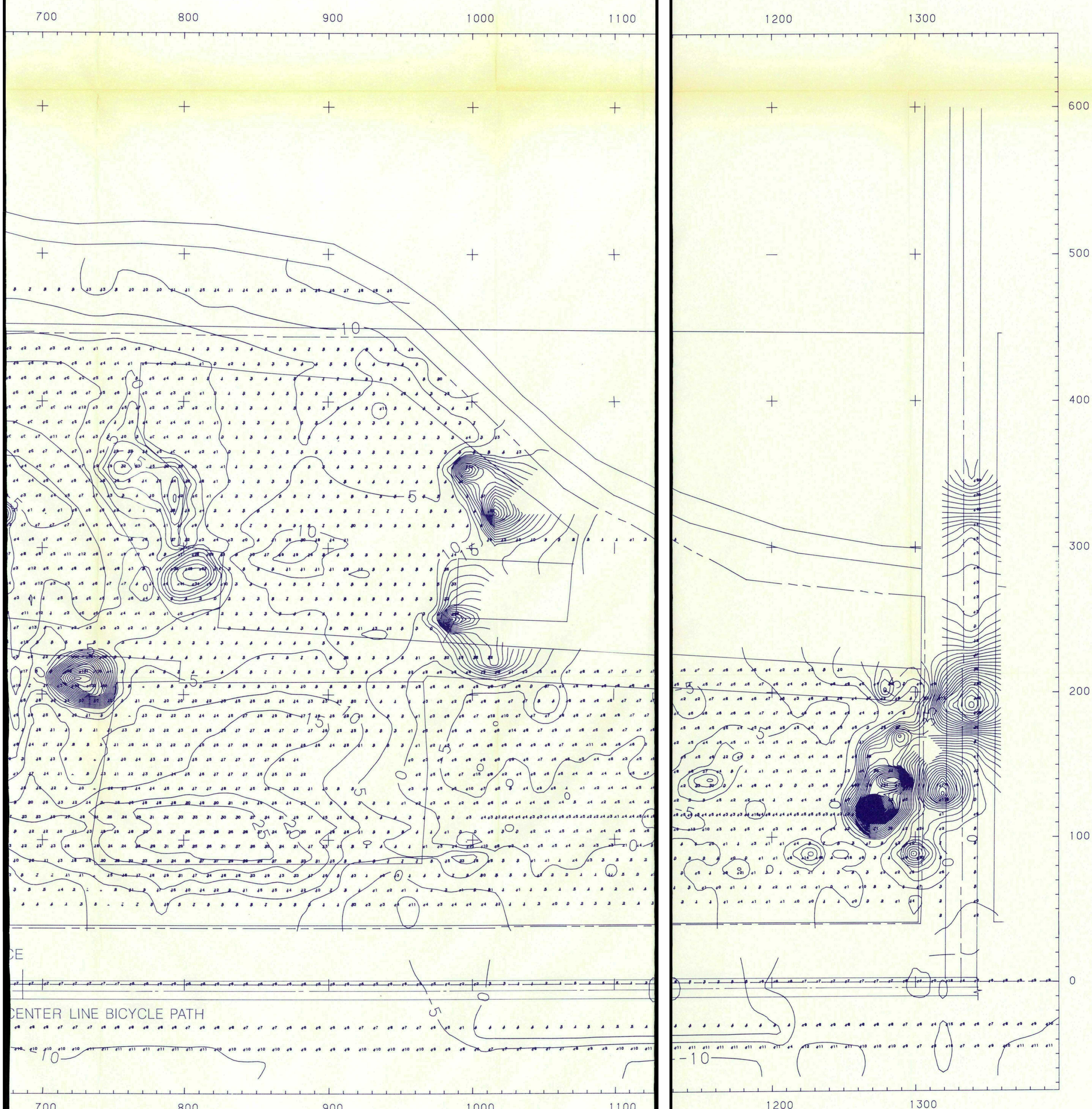
CHAIN LINK FENC



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NORTEC

Geophysical Survey and Site Sampling Investigation

Western Processing Site
Kent, Washington
1987

E.M. Inphase Component Map

Project Number	44-01-02
Date	March 6, 1987
Project Manager	Ken Lepic
Design	Ken Scheffler
Architectural	
Structural	
Mechanical	
Electrical	
Drawn By	Tony Petrillo
Revisions	

PLATE 3

PLATE 4

Total Magnetic Field Intensity Map
Remedial Action Areas I, II, III, V,
IX & X

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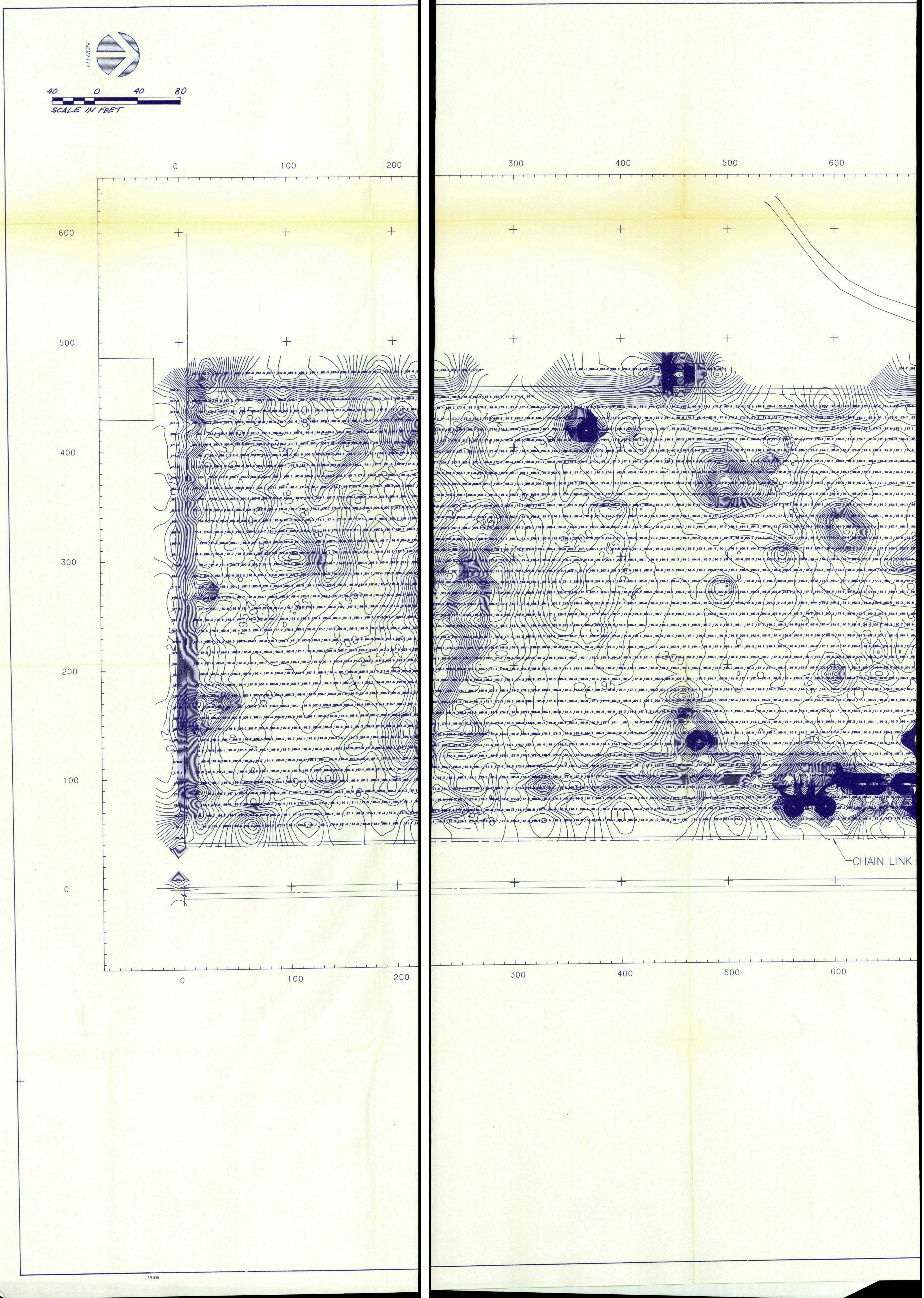
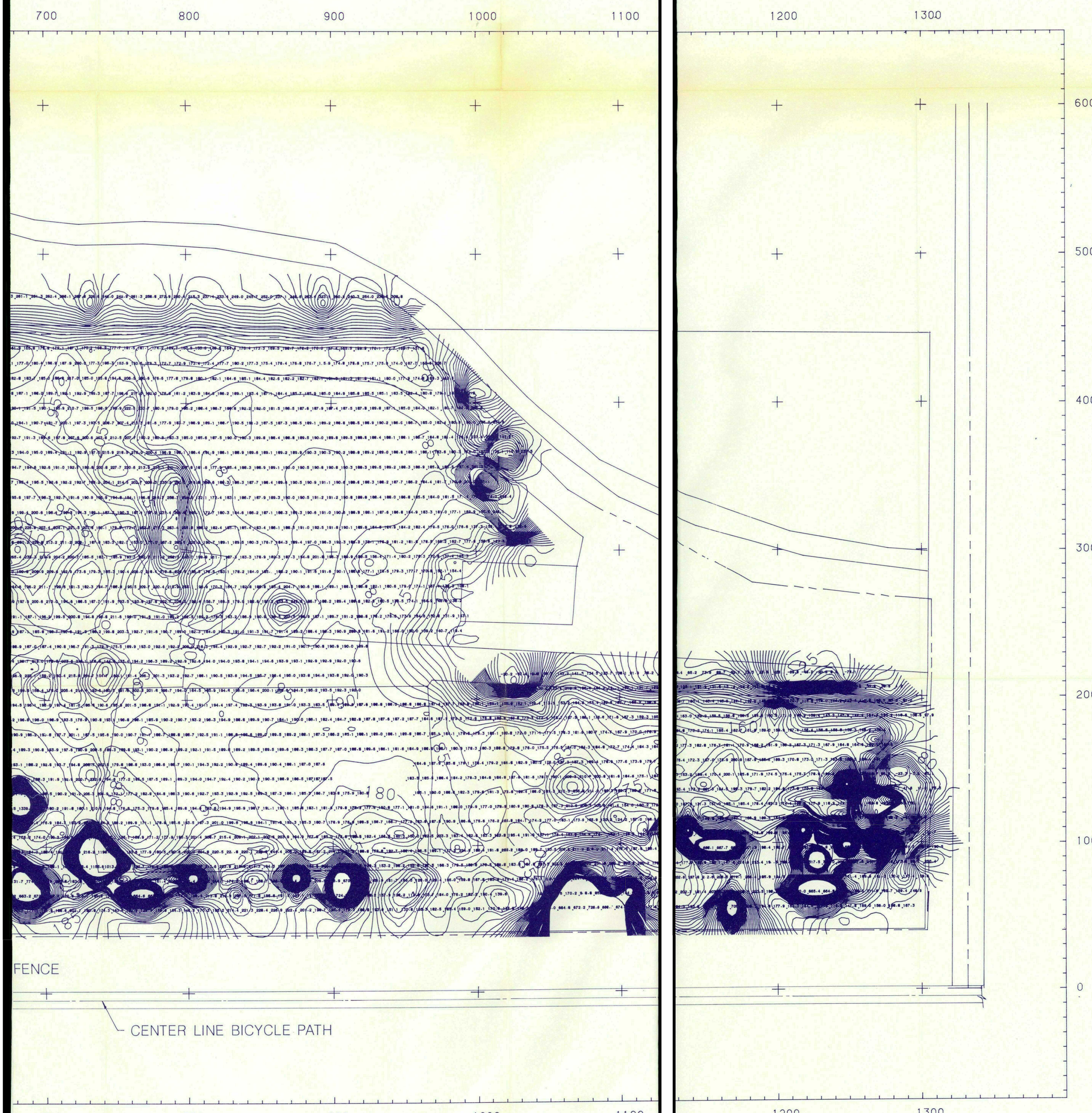


NORTH
40 0 40 80
SCALE IN FEET
0
100
200
300
400
500
600
CHAIN LINK
SR 839



HDR Infrastructure, Inc.
A Centerra Company

NORTEC

Geophysical Survey and Site Sampling Investigation

Western Processing Site
Kent, Washington
1987

Total Magnetic Field Map

Project Number	44-01-02
Date	March 6, 1987
Project Manager	Ken Lepic
Design	Ken Scheffler
Architectural	
Structural	
Mechanical	
Electrical	
Drawn By	Tony Petrillo
Revisions	

PLATE 4

PLATE 5

Vertical Magnetic Gradient Map
(0.5 Separation)
Remedial Action Areas I, II, III, V,
IX OO X

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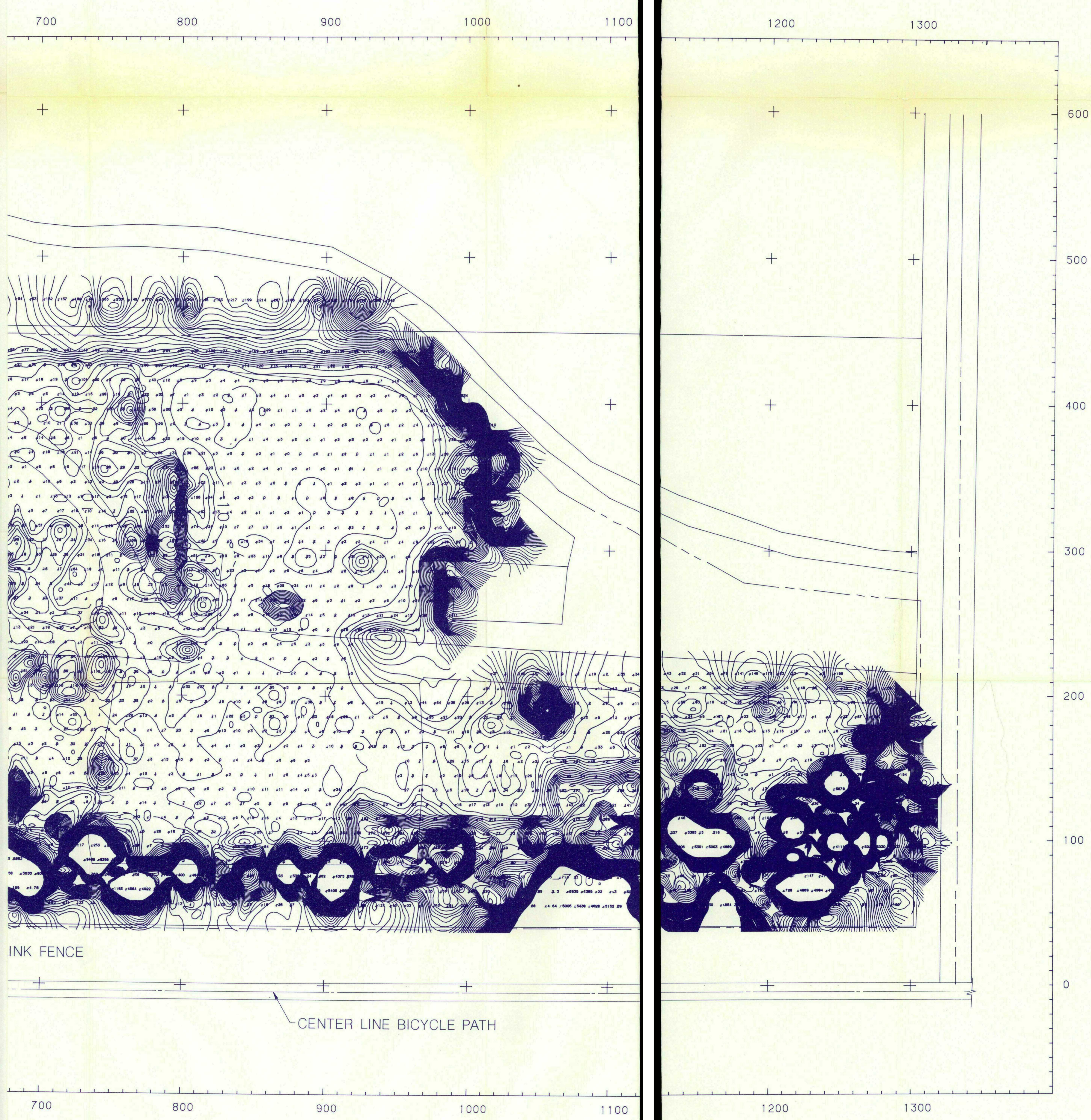
NORTH
40 0 40 80
SCALE IN FEET
0
100
200
300
400
500
600
-50
CHAIN L



HDR Infrastructure, Inc.
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NORTEC

Geophysical Survey and Site Sampling Investigation

Western Processing Site
Kent, Washington
1987

Verticle Gradient Map

Project Number
44-01-02

Date
March 6, 1987

Project Manager
Ken Lepic

Design
Ken Scheffler

Architectural

Structural

Mechanical

Electrical

Drawn By
Tony Petrillo

Revisions

PLATE 5

PLATE 6

Ground Penetrating Radar Map
Remedial Action Areas I, II, III, V,
IX & X

TARGET SHEET

Document ID PART OF 1518509

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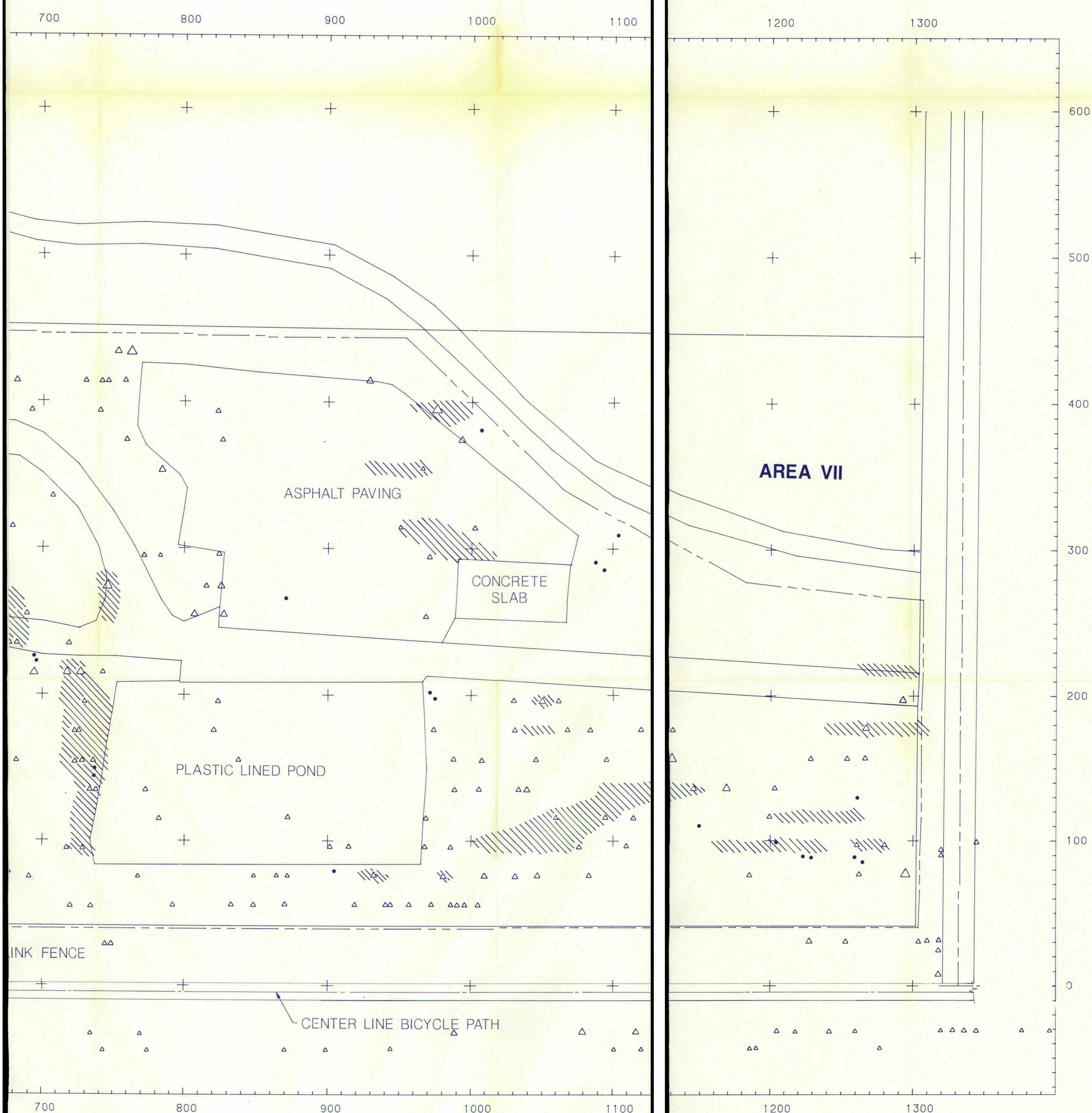
NORTH
40 0 40 80
SCALE IN FEET
AREA I
AREA II
AREA X
CHAIN L
0
100
200
300
400
500
600



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Geophysical Survey and Site Sampling Investigation

Western Processing Site
Kent, Washington
1987

Radar Target Map

Project Number	44-01-02
Date	March 6, 1987
Project Manager	Ken Lepic
Design	Ken Scheffler
Architectural	
Structural	
Mechanical	
Electrical	
Drawn By	Tony Petrillo
Revisions	

PLATE 6